Sights, Optics, and Accuracy

SONORAN DESERT INSTITUTE

SCHOOL OF FIREARMS TECHNOLOGY

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Chapter 1 - Fundamentals of Accuracy

Figure 1 : The Sharps 45-70 rifle was one of the most accurate firearms on the Western frontier, and was popularized by the movie Quigley Down Under.

Fundamentals of Accuracy

Webster's dictionary states that *accuracy* is "the degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard."[1] As a gunsmith, the biggest problem your customers face is the dilemma of accuracy: what is the "standard" of accuracy that my weapon can reasonably perform? The standard of accuracy in firearms is often measured in group sizes, but even that standard must be examined at length. First, though, we will explore the development of accuracy fundamentals from historical perspectives, to include prominent figures, rifle platforms, and ballistic

development through the centuries. Secondly, we will discover how ammunition, temperature, gravity, and other physical properties play a role in the terminal effect upon a target. And as a tertiary goal, we will diagnose the physiological acumen of the shooter, and, as gunsmiths, will learn to modify the mechanical attributes of the firearm to foster better performance for the end user. Undoubtedly, a gunsmith must possess an intricate amount of knowledge in these areas to effectively fulfill a customer's expectation of accuracy. Simply stated, at the end of this course, you will be proficient in the development of accuracy, its physical attributes, and the mechanical modifications necessary to develop the gun toward its highest potential.

DEVELOPMENT OF RIFLED ARMS

The first portable firearm was produced in the early 1300s. It was an unusual "Roman candle" type weapon used in northern Africa, and its use on the battlefield was limited to scattering pyrotechnics, thereby scaring horses and frightening enemy troops[2]. History goes on to record that in the 14th century, the first effective use of a firearm could defeat the plated armor of the medieval knights, and was met with great disdain by the "honorable" mounted kinsmen. However, the most landmark discovery related to firearm accuracy—rifling—was invented either by Augustus Kotter of Augsburg, Germany, in 1498, or by Gaspard Kollner of Vienna in the same century. Some believe that these pioneers slanted the feathers of an arrow, and in doing so, the feather created a higher amount of accuracy than those with straight feathers. Rifling in a gun barrel created a similar turbulent spin unlike an unmodified straight bore musket. Later attempts to perfect the spin rate of rifling included adding double grooves to vary the rate of spin within the barrel, also known as "gain-twist" rifling, found in early Colt revolvers[3]. Experiments and designs of rifled accuracy were abundant in cannonry throughout the intervening years from its inception to today. Unfortunately, for military small arms development, it was not until the 18th century that rifles would be prevalent in the hands of infantry soldiers.

Before the American Revolution, the German Jaeger flintlock was adopted by settlers in the Colonies, and eventually became the blueprint of both the Kentucky and Pennsylvania rifles of renown. From the onset of the War, these highly accurate rifles, coupled with guerilla tactics, gave the colonial defenders a large measure of "standoff distance" during the conflict. Elsewhere, although rifled muskets existed in France, the cost was too excessive for military leaders, and, as a result, Napoleon withdrew the

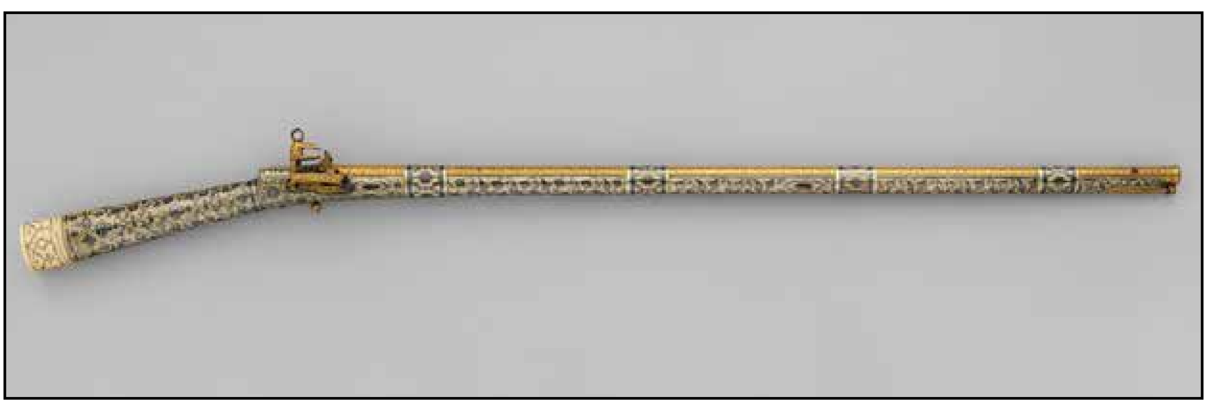

Figure 2: Pictured is a Miliquet lock rifle from the Caucus region of the Ottoman Empire, year 1860.

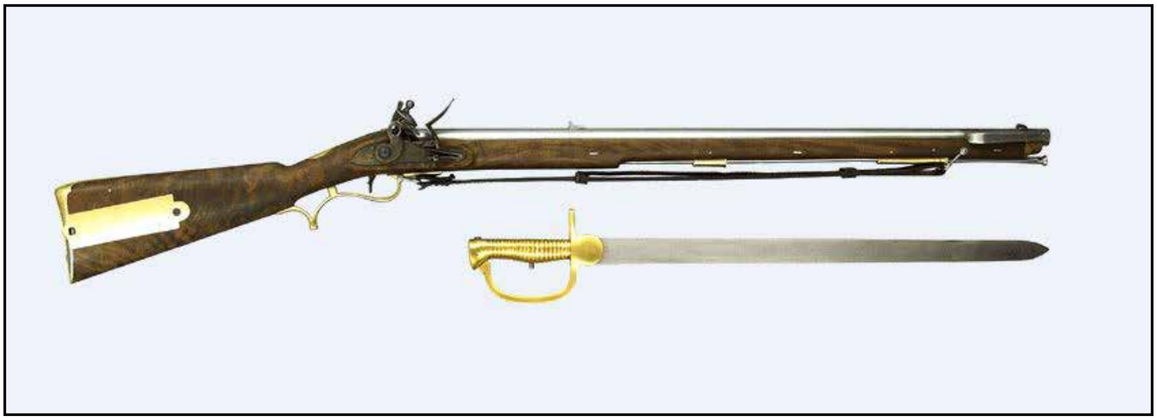

Figure 3: The J. Baker Rifle was an early American reproduction of the Jaeger flintlock.

rifle from his troops†. By and large, however, armies across Europe started to adopt the rifle, and by the 19th century, the smoothbore musket quickly became a relic for combat use. Privately, the rifle was ubiquitous in use by the sportsmen in the European aristocracy, and designs of these rifles became ornate and expensive.

As it is with many popular items, chiefly firearms, manufacture and development became popular in Europe among the masses, but even more so in the rugged backwoods of the Americas. One such advancement in history was made by Frenchman Honoré Leblanc—the first man in history to perfect interchangeable flintlock parts for mass production at the Château de Vincennes arsenal in 1785. Leblanc even displayed his method of producing rifles to the American Minister to France, Thomas Jefferson, with resounding success. Upon his return, Jefferson promoted Leblanc's idea of interchangeable parts manufacturing in America. In 1798, Eli Whitney wrote a contract to supply rifles using this new technology. However, it took eight years of R&D and prolonged manufacturing before Whitney produced the 15,000 firearms promised in his agreement[5].

In 1851, the next leap forward of weapons design was of French origin, this time by Mr. Claude-Étienne Minié and his elongated conical musket ball. Deemed the "minié ball" to the Americans, this invention helped stabilize the projectile during its path from the breech to the muzzle, or *internal ballistics*. First used in the Crimean War, the development gained immediate popularity with paper cartridges, and later with brass cartridges. Weapons development in

Figure 4: A French Army officer, Claude-Étienne Minié developed the first conical point projectile. He later worked as a manager for the Remington Arms Company.

† A notable exception was the French troops in the Algerian campaign, who noticed pointed accuracy out to 200 meters with great success. In the 1830s, rifles were reintroduced to the French troops.

Paris flourished, and the French influence continued with the development of the self-contained paper cartridge (Samuel Pauly, a Swiss working in Paris in 1812), the first pinfire metallic cartridge (the .22 Short by Louis Flobert in 1845), and the metallic centerfire cartridge (Monsieur Clement Pottet in 1829)[10].

Development of Projectile Trajectory

The first to theorize the science of projectiles as a curved flight path moving through space started with the father of ballistics, Niccolo Tartaglia, in 1537. Tartaglia noticed that the best angle for a bullet to move at a target was about 45°, and he also noticed that a cannonball had a slightly curved flight path. Galileo expounded upon this topic when he deemed that all projectiles form a specific *parabola,* or arced pattern, and published his findings in *The Two New Sciences* in 1638[6]. It is important to note that the understanding of drag and gravity had not yet been theorized, so Galileo's experiments did not include external atmospheric conditions in his equations. However, in 1686, Sir Isaac Newton, in his *Principa Mathmatica*, published a refined version of Johannes Kepler's principles of objects moving in flight, or *classical mechanics*.[7] Newton's laws defined the concepts of gravity and motion—topics that build the science of trajectory as we know it today[8]. Other advances in the 18th century include Dr. Benjamin Robin's landmark book on the topic of velocity, *New Principles*

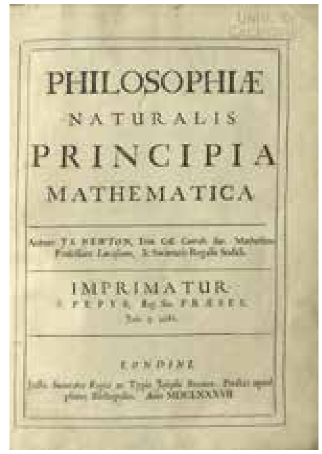

Figure 6: Considered one of the most important scientific works in history, Newton's Philosophiae Naturalis Principia Mathematica *formulated the physics of objects in motion.*

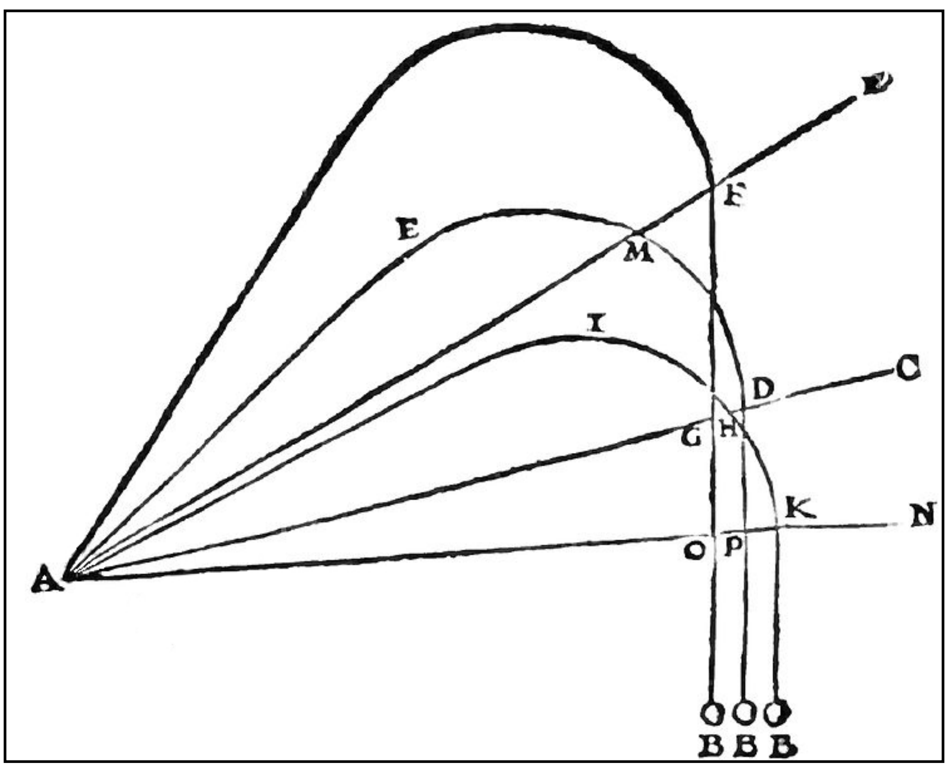

Figure 5: The curved flight path of a projectile was first envisioned by Niccolo Tartaglia in this sketch from 1537.

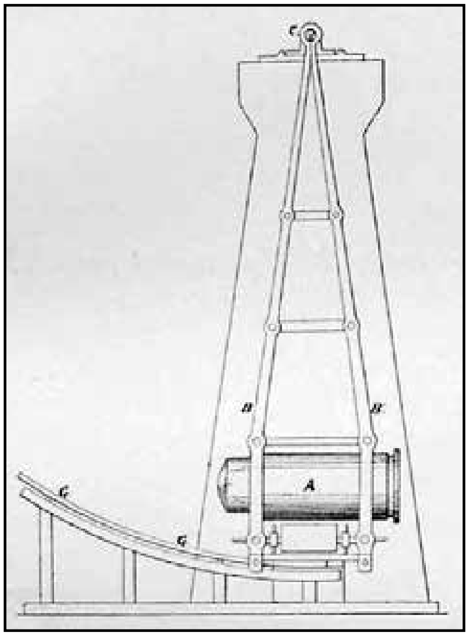

Figure 7: *Robin's patent of the ballistic pendulum, 1911.*

of Gunnery, which was first published in 1741. Using the 8th Section of *Principa* as a reference, Robin created the first working *ballistic pendulum* to measure the speed in which moving projectiles move through space, and which became a forerunner to our modern chronographs [9].

Let us now get a glimpse of how physics calculations work in a much-abbreviated experiment:

1. First, let's define a projectile's *parabola* as an arc that is created due to the horizontal velocity and gravitational "drop" (parabolas themselves are simply curved surfaces). We will fire this weapon in a "vacuum" of sorts, so that wind, temperature, humidity, and other atmospheric conditions are all at 0. Figure 8 is a classic example of a projectile's trajectory until it terminates on the ground.

2. Figure 9 is classic Galileo's parabolic shape for projectiles. We'll come up with a slightly more realistic range model in the next example. **Our problem will be to calculate the amount of bullet drop from a rifle shot from a level surface to a 200-meter point target.** Let's assume that our projectile is leaving the muzzle of our weapon at 1,300 ft. per second (ft/s). We need to calculate this number into meters:

1 foot = .3048 meters

1,300 ft. / .3048 = 396 meters

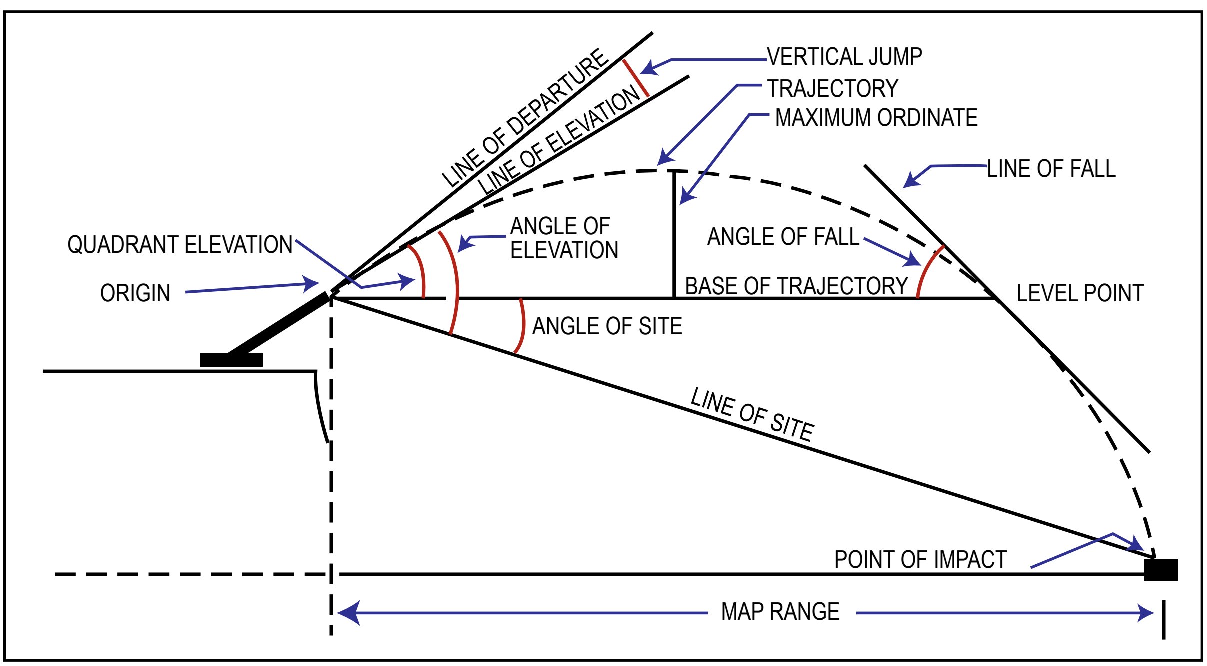

Figure 8: Components of a projectile's trajectory.

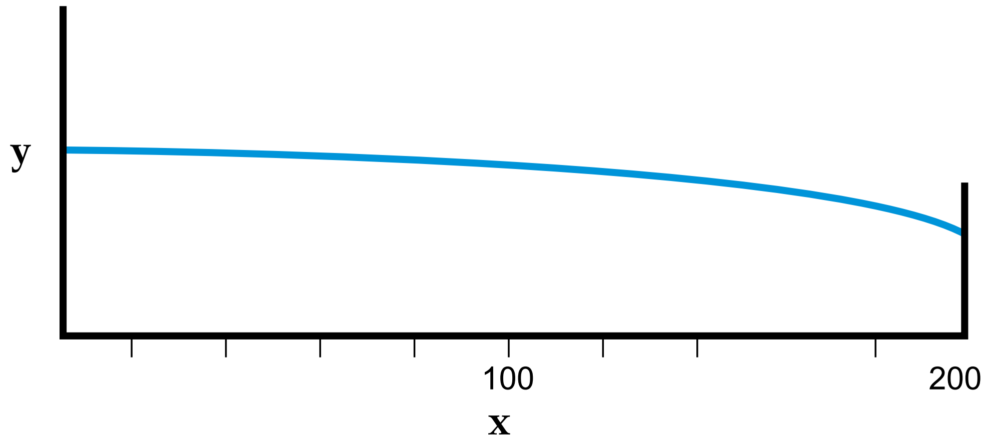

Figure 9: Galileo's parabolic shape for projectiles.

It's important to use meters instead of feet since the equation for the *acceleration of gravity* is 9.81 m/s^2, and it makes the math *a lot* easier in the end.

3. Okay, so now that we have all our given data, we'll need a type of equation. In physics, motion is used in a specialized family of Galileo's equations, also known as SUVAT:

s = Distance

u = Initial velocity

v = Final velocity

a = Acceleration

t = Time

So, let's plug it in for <u>the x-axis</u> only. This is the calculation of the *horizontal motion* of the projectile as it leaves the barrel. Because there is no force of wind to hinder the bullet in our example, nor is there a force of thrust (like a rocket) to speed up the bullet, the horizontal acceleration remains at 0. This also means that initial velocity and final velocity are the same.

s = 200 m

u = <u>396.21 m/s</u>

v = <u>396.21 m/s</u>

a = 0

t = ?

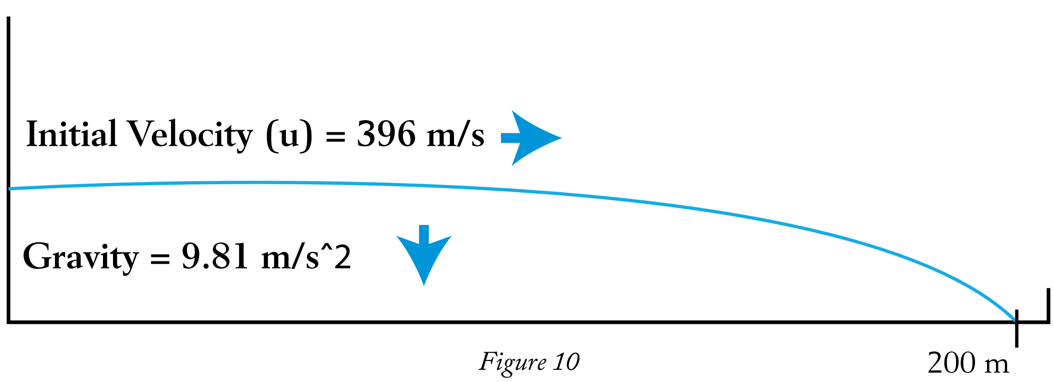

Figure 10

We need to figure out the time of flight, so we'll use this formula:

$$t = \frac{s}{v}$$

$$t = \frac{200}{396.21} = \underline{0.50478\ \text{sec}}\ \text{(total time of flight)}$$

So, let's plug it in for <u>y-axis</u>. This is the calculation of the *negative motion* upon the bullet, namely the acceleration of gravity's effect on the projectile.

s = ?

u = 0

v = ?

a (or gravity) = <u>9.81 m/s</u>$^{-2}$

t = 0.50478

Let's solve for the distance of downward motion, S. This requires another SUVAT equation:

$$S = ut + \frac{1}{2}at^2$$

$$s = t(0) + \frac{9.81 \cdot (0.50478)^2}{2}$$

$$s = \frac{9.81 \cdot .2548}{2}$$

$$s = \frac{2.4996}{2}$$

$$s = 1.249\text{m}$$

To make it easier, we'll divide the entire equation by 2 instead of multiplying by ½. Also, notice that the multiplication of the ***ut*** value will become zero since our value of ***u*** is 0.

This number, 1.249m, is the distance of bullet drop the round experiences at the distance given the rate of initial velocity of 396 m/s over the span of 200 meters in a direct fire test environment.

Now, remember, we're dealing with a "test" environment where we are only factoring in the time of flight as measured by the velocity of the projectile at a certain distance. More complicated ballistic equations are found when we determine the mathematical values of temperature, muzzle velocity, form factor, ballistics coefficient, air resistance, altitude, barometric pressure, angle of attack, and many more. The good thing about our modern world is that we can use specific ballistics calculators that will make these adjustments for us on the range, as we'll see in the next chapter.

INNOVATIONS OF RANGE CALCULATIONS

During the Industrial Revolution, the term "computers" referred to "men who compute," or trained mathematicians that used manual trigonometry and calculus tables to estimate ballistics[11]. Due to the complication of the gunnery calculations, attempting to "dial in" a flight path based on manual calculations became daunting and inaccurate. From 1873 to 1898, in France, the Gavre Commission attempted to predict a

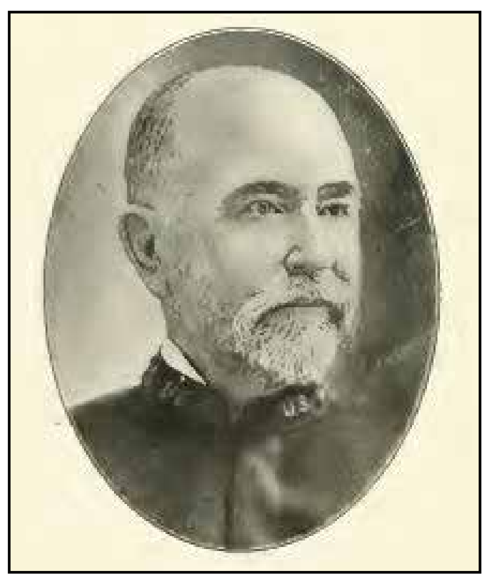

Figure 11: Colonel James Ingalls' work on ballistics pioneered the use of military arms in the U.S. for over 100 years.

standard model of projectiles that would help scientists understand the atmospheric behavior of projectiles. Pioneers such as German Friedrich Krupp, who formed the knowledge of air resistance upon a bullet, Russian Col. Nikolai Mayevsky and Francesco Siacci, who calculated the dimensions of a "standard bullet," and American Col. James Ingalls, who refined the ballistics coefficient for the U.S. Army, all played key roles in this development. The G_1 number, or "Gavre" number, was discovered, and streamlined the form of military projectiles, which had a more round-nosed shape. Ingalls' famous work with the U.S. Army's Field Artillery Division, *Interior Ballistics*, can be found at https://archive.org/details/interiorballisti00ingauoft. These tables were used by gunners for over 100 years until the advent of modern computing.

Before we get to the calculation of the ballistics coefficient (BC), we must incorporate Newton's *sectional density* equation, or mass (M) divided by the squared diameter of the bullet in inches (d). The unit of mass is the pound (lb.) in this equation, but a smaller measurement had to be developed called the *grain*, or 1⁄7000 of a pound, to accurately note the light weight of a projectile. Thus, the calculation looks like this:

$$Sectional\ Density = \frac{M_{gr}}{7000 \cdot d_{in}^2}$$

$$Ballistics\ Coefficent = \frac{Sectional\ Density}{Form\ Factor}$$

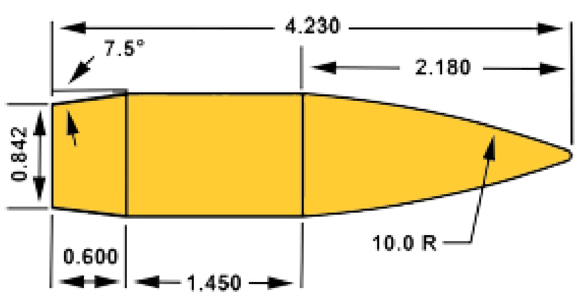

Figure 12: Dimensions of the standard G7 projectile form factor.

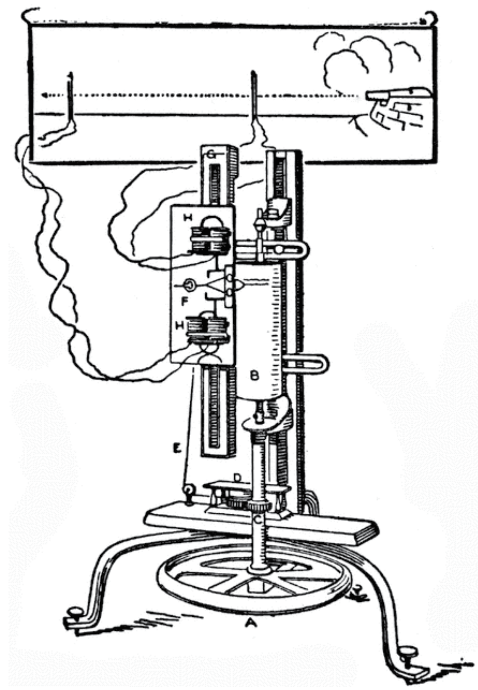

Figure 13: Bashforth's patent of the electrical chronograph, 1866.

Since the shapes of bullets affected the math of the BC, scientists now use about 11 separate *form factor* numbers to account for the shapes created by bullet manufacturers. The two most popular numbers of bullet designs are the original G_1 (round-nosed) and the Spitzer—or boat-tail—shape, which is known as the G_7 calculation. Most handgun ammunition and flat-based projectiles, such as a .22LR, use a G_1 calculation and projectiles that are meant for long range shooting typically use a G_7 calculation. Remember that the BC changes as the speed of the round diminishes upon leaving the muzzle, so multiple measurements are taken during the flight path.

As stated before, the first measurement of a bullet's velocity was Robin's pendulum in the 1700s. However, the first electro-mechanical method of measuring exterior ballistics was invented by Oxford professor Francis Bashforth in 1867. His method was to place electrically powered copper screens at both the muzzle end of the cannon as well as near the target. Once the projectile broke

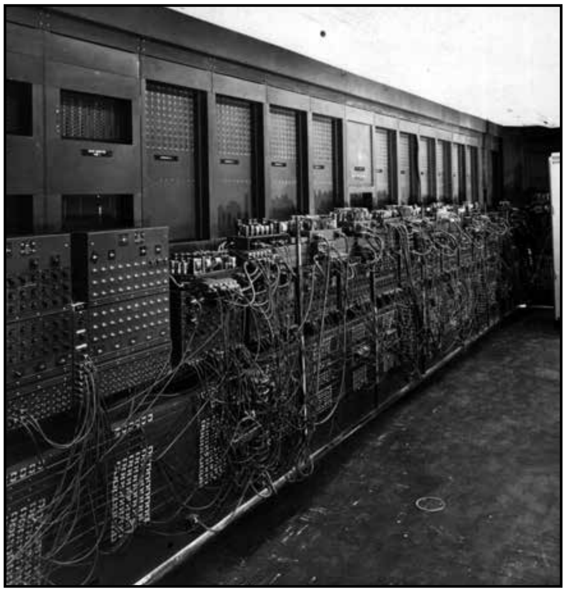

Figure 14: One of the first electrical computers in the U.S., the ENIAC was developed by the Army's Ballistics Research Laboratory.

the copper barrier, a mechanical measurement was taken to subtract these numbers and to determine the overall time of flight. Much later, in 1946, a team in Philadelphia developed the first fully electronic programmable computer—the ENIAC—a project run by the U.S. Army's Ballistic Research Laboratory, which completed this type of differential calculus in seconds[12].

One of the major benefits of our digital world is to rest upon the laurels of programmers and technicians to develop complex software to range and estimate ballistics calculations. In the 1970s, a man by the name of Robert Whyte designed a computer code that predicted the geometry of a bullet not by a "standard model" such as the G_7 number, but rather by a bullet's *individual* aerodynamic behavior and geometry. In 1987, Mr. Whyte, along with a fellow scientist, Bud Stearns, founded the company Arrow Tech, which developed *PRODAS*, their signature software. By integrating methods of doppler radar, *PRODAS* is considered the gold standard of measuring the projected flight path of bullets, and is used by defense manufacturers and bullet manufacturers alike[13]. One test that was completed recently by the Barnes Bullet Company shows the differences in Figure 15 (the "test bullet" uses the PRODAS number).

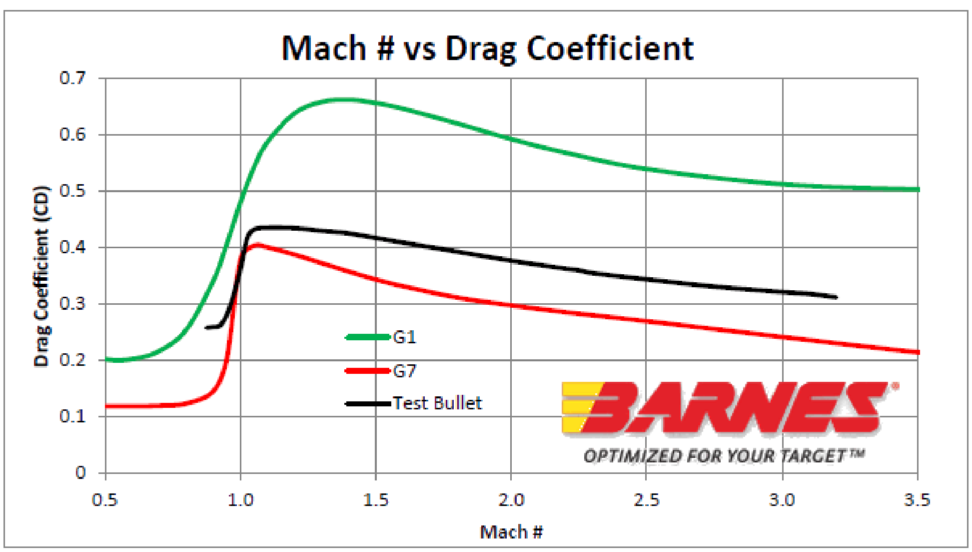

Figure 15. Test fire comparison between the G_1, G_7, and Doppler (test bullet) trajectory.

Achieving Rifle Accuracy

For the gunsmith, the most important task is to understand how to develop accuracy within a rifle platform. The quality of the craftsmanship of a gunsmith's endeavors in accuracy is to achieve the highest possible accuracy within the means, cost, purpose, and ability of the shooter. For example, the customer who only wants an accurate hunting rifle to achieve 1 MOA may be different than the competition benchrest shooter who would want 0.5 MOA or below just to qualify. Also, understanding the type of weapon that is being accurized will play a large role in advising the customer; they may want their 70-year old Enfield to consistently shoot 0.3 MOA, but it's just not going to happen. The first step in achieving this type of accuracy is to understand the basic components of a firearm, specifically a rifle, and how these components factor in accuracy.

Figure 17: This hunter's crown needs touching up on a lathe or precision reamer.

Crown. The first component we will discuss is a rifle's crown. A crown is the very tip of the bore in which the exit plane is precisely machined perpendicular to the bore axis. Since it is the last portion of the barrel that will *physically* contact the projectile, it must be machined perfectly perpendicular to the bore axis. The geometry of the crown is of most importance because the dispersion of gasses that surround the bullet must be concentric to create a stable flight path. Mechanically, a gunsmith can achieve an accurate result from a perfect 90° crown done on a lathe. Some competition shooters prefer this type of crown, but the rifle must be perfectly

Figure 16. The Army M24 Sniper Weapon System was a platform used from 1988-2010 based upon the Remington 700 series of hunting rifles.

Figure 18: Figure 18. An example of the Browning BOSS adjustable muzzle device

maintained since the crown is easily damaged. If the firearm is to see any heavy use other than the range, there are four other types of crowns to be considered: a beveled crown, an 11˚ crown, a round or "hunter's crown," and a hybrid flat crown with beveled edges. These crowns are cut on the lathe or by using a precision hand tool, and are perfectly countersinked to create the same perpendicular exit plane.

Harmonics. The most important aspect of rifle accuracy is learning how to achieve a stable and harmonic barrel. Barrel harmonics is the measure of a barrel's ability to return to true upon firing a round, and ensures that from shot to shot, a consistent barrel movement is achieved. The desired result is for the barrel to act as a piano tuning fork that returns to zero after the barrel vibration ends, but several mechanical improvements must be made to achieve this result. Each time a bullet is fired, the pressure curve peaks first at the chamber and continues throughout the travel of the bullet down the barrel. Slow motion cameras may capture this contorting "whip-like" effect of the barrel, especially a thin barrel that does not have a muzzle device.

A gunsmith is recommended to install a heavier barrel or heavy muzzle break to limit the vibration and enable the barrel to be rigid. A well-designed muzzle device and/or suppressor will also have a positive effect on accuracy since the increase of gas pressure leaving the barrel will lead to a higher muzzle velocity downrange. A popular adjustable muzzle device is the Browning's BOSS system, which allows you to tune the harmonics of the device by caliber and bullet weight. The most important aspect of a barrel's harmonics is to make it as stable and rigid as possible, but we also must consider field use and weight for those who use a rifle for hunting and/or tactical sports.

Rigidity of the barrel can also be obtained by fluting a barrel (Figure 19) or machining grooves lengthwise along the barrel's profile. The effect of fluting is often misunderstood, but there are positive aspects in completing this task. First, it is important to note that spiral-fluted and triangular-fluted barrels are preferred over straight-fluted barrels due to their unique geometry. The reason why flutes add rigidity is because they decrease the "area moment of inertia," which measures how the pressure dissipates around the circumference of the barrel.[14] Fluting also helps in saving weight and cools down the barrel like the heat sink on a computer. Over time, this allows the barrel's point of impact to remain more consistent than a heated barrel. Manufacturers will complete the fluting before either heat stressing from 750˚ to 1,400˚, or to cryogenically stress relieving at -300˚.

A newer development in barrel harmonics is the "traveling wave theory," which is "the pressure pulse from the gasses in the chamber, causing a traveling wave of stress that bounces back and forth along the barrel between receiver and muzzle, slightly changing the bore diameter in the process."[15] This theory is also known as barrel "ringing," in which the acoustic stress of the firing pressure resounds four to five times throughout the barrel *before* the bullet leaves the muzzle. This process even distorts the lands and grooves of the barrel and must be limited as much as possible. Again, dampening

Figure 19: An AR-10 pattern rifle with a spiral-fluted barrel.

the amount of barrel ringing can be done with proper barrel tuning, machining, weighted barrels, and even muzzle devices.

Bedding and Stabilizing. A key element in improving accuracy is to glass bed and free float the barrel. Bedding is a process in which the stock and tang are infused with epoxy that surrounds the action and barrel. The compound must not create a mechanical bond with any metal components, so a release agent such as wax must be used on the metal parts before the epoxy is poured. Bedding will ensure that the movement of the barrel terminates at the action and is not forced to contort upon the stock, thus creating instability in the barrel's harmonics. This is also done either with or without a "pillar," or a fluted metal bushing that surrounds the action screws and initiates contact with the bedding compound. In the end, bedding creates a more rigid stock and tang and is meant to consistently absorb the recoil of the rifle. An extreme measure found in some benchrest shooting matches is to completely glue the action to the stock, which fills the voids between the stock and the action but is near impossible to separate.

Further stability is achieved through free-floating the barrel, which is done to ensure that the forend does not bump against the barrel during its movement. In an older rifle, such as the Mosin-Nagant, the upper and lower stocks are fitted with sleeves (or bands) that are affixed to the barrel. This is not recommended, since the point of impact (POI) will shift based on the stresses of the wood and metal binding after each shot. Free-floating is achieved by removing wood or synthetic stock material around the barrel, all the way toward the receiver ring. Some firearms include a barrel block that will precede the action and give further stability to the firearm. Another useful tool is to inlet a stabilizing bar (Figure 20) into the forend of the rifle, such as the Savage™ Accustock®, or the Accuracy System™ Harmonic Barrel Stabilizer® for gas guns.

Triggers. The amount that a trigger is consistently accurate is 100 percent subjective, but most of the time a lighter trigger will be requested by the shooter. It should be noted that a trigger is not a primary mechanism that affects accuracy, but it does affect the shooter's ability in timing an accurate shot. In older firearms, a gunsmith will be asked to mechanically modify the trigger for a client, and must be aware of the liabilities involved in performing this task. This may involve adjusting the trigger spring tension, sear disengagement geometry, and/or polishing the hammer. On average, a competition long-range match shooter will most likely want a 2lb. trigger, whereas a hunter should be suited with nothing less than a 3–4 lb. trigger. Most smiths these days ensure that liability waivers are completed by the customer before a task such as this is completed. A smith must be insured!

A safer alternative in adjusting newer triggers might be to install an aftermarket system such as Timney™, Triggertech™, and Shilen™. For the AR-15 style of rifles, there are drop-in triggers manufactured by Geissle™, Elftmann™, CMC™, and a host of other companies that produce adjustable triggers. Bolt-action rifle manufacturers, such as Remington™, Tikka™,

Ruger™ and Savage, produce their own adjustable triggers, but aftermarket units are available. The gunsmith's job is becoming scarce as it relates to trigger jobs; even military surplus rifle triggers, such as the WWII Japanese Arisaka, now have an aftermarket counterpart. For the pistol enthusiast, there is still work for a gunsmith to modify either a 1911 and revolver triggers, but an extensive amount of knowledge must be obtained before tuning these firearms. Some gunsmiths tend to stick to one family of firearms, such as S&W® handguns, so a specialist is someone who will have knowledge in this area. Furthermore, as a gunsmith, it is critical to network with these smiths in case you are unfamiliar with how to perform these tasks.

Blueprinting. Blueprinting, or truing, the action of a bolt-action firearm is comprised of four main tasks: facing the action, truing the bolt face, lapping the lugs, and recutting the action threads. Accuracy is improved when all the engagement between the barrel and action is completely centered to the bore. Facing the receiver ring, or the threaded portion of the action, is crucial to the concept of barrel harmonics and overall accuracy. Even details such as the threads in the receiver ring and concentric vent holes in the receiver must be an exacting measurement to ensure that the equal force of the recoil is applied in a consistent manner. As author and scientist Harold R. Vaughn writes, "Barrel vibration is directly related to the *moment* in the forward receiving ring… For instance, if you apply a one-pound vertical force at the muzzle (24-inch moment arm) a 24 inch-pound moment will result at the forward receiving ring…".[16]

Facing the action is completed by inserting the action into a chambering and truing fixture. A facing mandrel is then inserted into the receiving ring and placed in between the lathe centers. Using a dial indicator, the mandrel's concentricity is measured and should be as close to zero as possible. From here, the lathe can properly face the action until it is true. A proper kit, such as the Manson Precision™ Receiver Accurizing System, should be purchased to tap the threads, to ream the lug abutment, and to ream the lugs themselves. The piloted tap that comes with the kit will also double as an action reamer; so the kit, although expensive, will save time and money in the long run. It should be noted that some smiths

Figure 20: The Savage Accustock is a synthetic stock that includes an aluminum chassis to increase rigidity. Also included in the system is the Savage Axis™ adjustable trigger system.

do not prefer to cut the action threads, since it may lead to destressing the receiver, so proceed with caution and do your research. A visual representation of the process can be seen at www.lonestarfab.com/gunsmithing/remington_700-rebuild/remington_700_rebuild.htm.

Chambering and Rechambering. The work that has been done to blueprint the action and bolt engagements means nothing if the barrel is also out of spec. The barrel is the instrument of accuracy and must be as concentric and centered to the action as much as possible. The chamber of the barrel is comprised of five key areas: the throat, lede, body, first neck, and second neck. These areas are often cut at the factory; however, many manufacturers do not use a piloted reamer for many "off the shelf" models of firearms. This allows a gunsmith to make a living in rechambering old rifles using precise piloted reamers. Some great reamers are made by Dave Manson™ and by Pacific Tool and Gauge (PTG)™.

Another key aspect of chambering and rechambering is when a customer asks to convert the existing cartridge into a new cartridge altogether. When you plan to rechamber a rifle, ensure that the firearm is in shape to accept the new load. There are mainly two types of actions: long and short. Of these, there are *generally* four different face dimensions that are used in firearms: 0.384, 0.473, 0.540, and 0.585 (+/- for each). *See caliber conversion chart on the next page.*

For example, a relatively simple conversion is to go from .243 Winchester to .308 Winchester. Although a new barrel is needed to rechamber for the .308 rifle, the short action of the .243 can be used; and more importantly, the bolt face dimensions are the same. Caliber conversions get a bit easier with Savage Model 10/100 actions since the bolt faces are able to be replaced without changing the entire bolt (not so with Remington 700s and others). PTG also sells many precision bolts for precision firearms, along with any Savage face replacements you may need.

MEASURING RESULTS

The conventional testing platform for all firearms is related to shot dispersion on a target. The development of precision shooting also came with some very different methods of measuring shot placement. There are eight historical measurements of precision, but we will only discuss the three in common use today: extreme spread, mean radius, and circular error probable.

Before we begin, we must clarify the distance of angular measurements from the firearm to the target. The two most common measurements in firearms accuracy include minute of angle (MOA) and milliradian (mil). To calculate MOA, we must remember that each circle has 360°, thus the *minute of angle* is easily measured by breaking up the degrees in a circle into 60 smaller units, or *minutes* (1/60°= 1 minute). Therefore, we multiply 60 x 360 and get 21,600 total minutes in a circle. Fortunately, the Imperial measurement of inches is equal to 1.047 minutes of angle at 100 yd. Since this can be scaled, we can assume that one MOA is *approximately* 3 in. at 300 yd., 4 in. at 400 yd., and so on. For those who use the English or Imperial system, measuring group sizes has become an easy chore, and in the U.S., this is a preferred method of measurement for civilian shooters who shoot at small distances. If a firearm is *less*

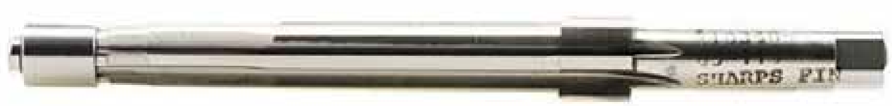

Figure 21: A precision reamer, such as this 6mm Norma, is used by gunsmiths to cut the chamber in a custom barrel, or to recut a chamber in an old barrel with the same bore dimensions.

Caliber Conversion - Bolt Face Dimension Chart

Short Action					Long Action				
Face Dimensions (+/-)	**0.384**	**0.473**	**0.540**	**0.585**	***Face Dimensions (+/-)***	**0.384**	**0.473**	**0.540**	**0.585**
17 Remington	x				220 Swift		x		
204 Ruger	x				6mm Remington		x		
222 Remington	x				240 Weatherby Mag		x		
223 Remington	x				257 Roberts		x		
225 Winchester		x			25-06 Remington		x		
22/250 Remington		x			6.5x55 Swedish		x		
6mm Norma BR		x			270 Winchester		x		
243 Winchester		x			7x57 Mauser		x		
250 Savage		x			7x64 Brenneke		x		
260 Remington		x			280 Remington		x		
6.5/284 Norma		x			30/06 Springfield		x		
7/08 Remington		x			8mm Mauser		x		
284 Winchester		x			338/06 A Square		x		
300 Savage		x			35 Whelen		x		
308 Winchester		x			257 Weatherby			x	
338 Federal		x			264 Win Mag			x	
35 Remington		x			270 Weatherby Mag			x	
358 Winchester		x			7mm Remington Mag			x	
223 WSSM			x		7mm Weatherby Mag			x	
243 WSSM			x		7 STW			x	
25 WSSM			x		7mm Remington Ultra Mag			x	
7mm Remington			x		300 H & H			x	
7mm WSM			x		300 Winchester Mag			x	
300 Remington			x		300 Weatherby Mag			x	
300 WSM			x		300 RUM			x	
325 WSM			x		303 British			x	
350 Remington Mag.			x		8mm Remington Mag			x	
					338 Winchester Mag			x	
					340 Weatherby Mag			x	
					338 RUM			x	
					375 H & H			x	
					375 Weatherby			x	
					375 RUM			x	
					416 Remington Mag			x	
					458 Winchester Mag			x	
					458 Lott			x	
					30/378 Weatherby				x
					338 Lapua				x
					338/378 Weatherby				x
					378 Weatherby Mag				x
					416 Rigby				x
					416 Weatherby Mag				x
					460 Weatherby Mag				x
					470 Nitro Express				x

Figure 22: This five-round shot group is well within 1 MOA at 100 yd.

than or equal to an MOA, it is considered an acceptably accurate firearm. For benchrest competition shooters and others who achieve more accuracy, .5 of an MOA or lower is desired. To simplify scope designs, manufacturers are now using the "Shooter's MOA," or SMOA, which automatically rounds the MOA measurement down to the precise inch. Some rifle scopes will now calculate ¼ in. drop at 100 yd. SMOA adjustment rather than actual MOA itself.

Milliradian is a measurement that is ubiquitous in the military and countries that use the International System of Units (or SI). A *milliradian* is measured as the 1⁄1000 of a "radian arc" in a circle. A *radian arc* is the distance that the radius of a circle travels around its circumference, which is simply , or 6.2832. To get a milliradian, we multiply this number by 1,000 and get 6,283 total mils in a circle.[††] For those who use the metric system, a mil is measured at exactly 10 cm at 100 m. Therefore, 1 mil is exactly 20 cm at 200 m, 30 cm at 300, and so on. Mils represent a larger overall scale as compared to MOA, but the scientific measurement of centimeters is more precise and easier to remember once learned. The good thing about most mil-dot scopes is that they use 1⁄10 mil adjustments. For example, one "click" at 200 m equals a total of 2 cm of travel, which is close to 1 in. at that distance (2.54 cm = 1 in.). It is common for shooters to also convert mils to MOA as well: e.g., 1 mil =10 cm or 3.15 in. at 100 yd. ††

Extreme Spread. By far and above, a popular method of testing accurate results is using the *extreme spread*, or center-to-center (CTC). This is done by taking calipers and measuring the overall length of the shot pattern from the center of two bullet holes on opposite extreme distances. A common practice for shooters is to

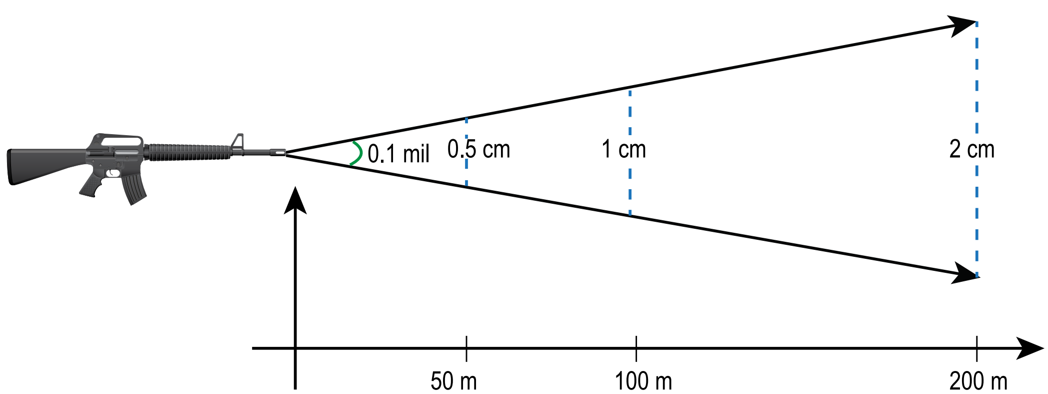

Figure 23: Visual representation of the 1/10 mil adjustments at various distances.

[††] *To complicate matters a bit, the U.S. Army maintains there are 6,400 mils in a circle, and the Russian scopes contend there are exactly 6,000 mils in a circle. These are estimates used by the military to estimate ranges to the target area.*

measure the group disregarding a "flyer," or an unusually errant shot, but this is not the case in the CTC calculation. The problem with the extreme spread is that the disparity between two data points does not accurately represent the precision of each shot within a pattern since only two shots per group are measured. This distance is either measured in inches or centimeters on the target itself. **An extreme spread of 2 in. is generally acceptable at 100 yd.**

Mean Radius. A more precise form of measuring the shot pattern is the *mean radius.* A mean radius is the total measure of all shots measured from a *desired mean point of impact*, or DPMI. To figure out this number, we must graph the shot pattern as follows:

1. Draw a graph using the plot of the x-axis as the bottom plane of the lowest shot, and the y-axis as the left edge of the left-most shot. This will represent your total shot placement area.
2. Measure the plotted distance from the x-axis to the center of each bullet hole, and add these values together.
3. Average the distance divided by the number of shots taken (total distance/shots).
4. Repeat steps 1–3 on the y-axis.
5. Plot the averages of the x- and y-axis on your graph. This number is now your *desired mean point of impact*, or DPMI.
6. Once the DMPI is found, a line is drawn from it to the center of each shot placement. These distances are also averaged, and the *mean radius* is now found. **An accurate mean radius maximum average for a rifle at 100 yd. is less than or equal to 1 in. (<=1 in.).**

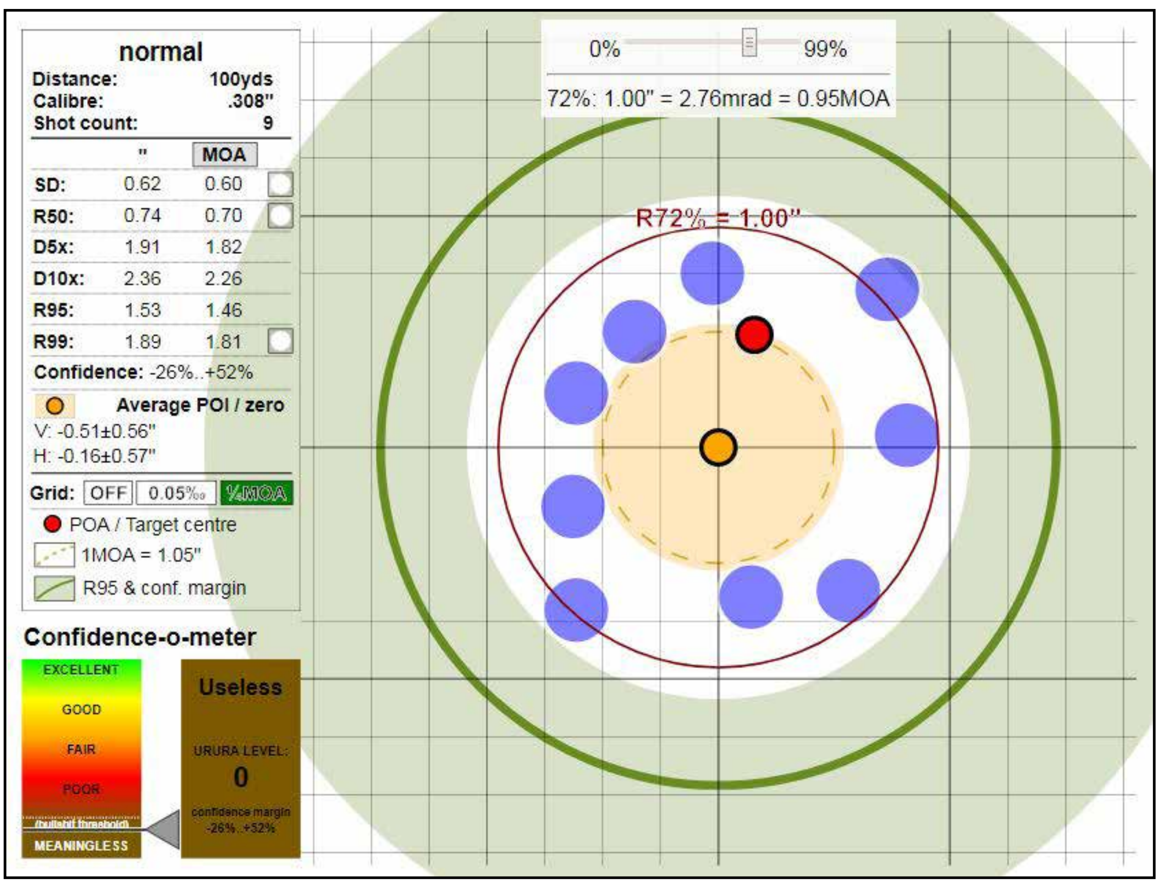

Figure 24: A test result using a .308 caliber rifle at 100 yd. The "R50" number represents the mean radius.

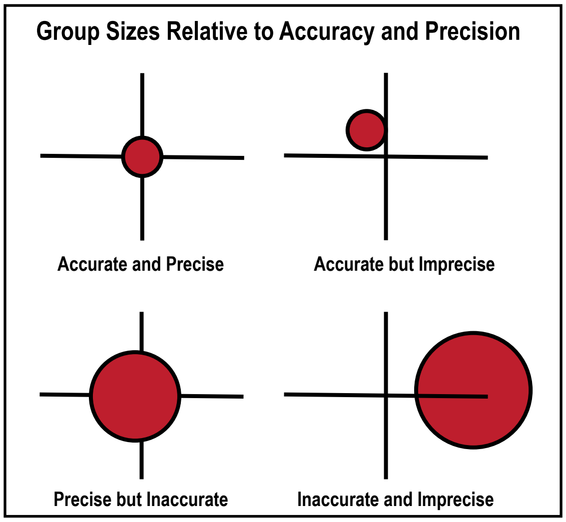

Figure 25: Basic example of the differences between accuracy and precision. The goal of the CEP is to determine how imprecise a firearm shot is based upon the proximity to the target.

To make life a little easier, a program called On Target Software™ Target Data System® will enable you to automatically plot this data just by shooting a printable paper target and scanning it into the software: https://ontargetshooting.com/ontarget-pc. Alternatively, an application called the Target Shooting App has been developed for use on smartphones and other devices: www.targetshootingapp.com. This tool will allow you to find the mean radius and other measurements in both mils and radians. Furthermore, a free online web tool called TARAN is also able to record these measurements.

Circular Error Probable. Imagine that we have shot 20 rounds on a bullseye target. Of these 20 shots, 10 land in the center circle, 8 land within the second circle, and the last 2 hit into the third circle. We can assume based on the data that this is a precise *and* accurate result. Therefore, Circular Error Probable, or CEP, measures the mean distance, or 50 percent hit rate, from the desired point of impact within a group of shot placements. Each error that exists outside of the 50 percent "hit zone" will decrease the precision of the rifle, shotgun, or handgun being used.

The CEP was first used to measure the hit rate for bombs and guided munitions. Therefore, although this is used commonly in military target acquisition, it is not commonly used in shooting sports. The reason we would use such a system for direct-fire weapons, such as rifles, is to measure both the precision and accuracy of a weapon independent of one another. For example, if the point of impact of a group (POI) is close together, but the group is located away from the point of aim (POA), the rifle is accurate, but not precise to the target. If, however, a group is not precise and is also inaccurate, measuring the CEP (among other types of measurements) is meaningless. CEP is measured as an inverse to a positive result, so a less than (<) 50 percent result is very good — a 0 is perfect (the actual function used for CEP is $0.62\sigma y + 0.5\sigma x$). Read more about CEP and more of the very complicated math functions used to calculate this measurement at Ballistipedia (ballistipedia.com). Practically speaking, a rifle shooting at 100 yd. should have a desired CEP of 0.5 MOA or lower from the point of aim (POA).

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Chapter 2 - Development of Gun Sights

Introduction

When firearms first developed in the 1300s, they had no sights (Figure 1). Flight of slow-moving stone projectiles could be observed by eye, with corrections dictated by the gunner's experience. By the late 1400s, it was the recreational and competitive shooters of Germany and the Holy Roman Empire who developed the modern precision features, including rifling and range-adjustable sights. While military arms were usually matchlocks (Figure 2), smoothbore, and limited to front beads for sighting, firearms made for hunting or carry by royalty were more often

Figure 1: The hand bombard cannon used no sights (circa 1390).

Figure 3: The rear leaf sight and dovetailed front blade are features of this wheel lock rifle.

Figure 2: A notch rear and front sight blade can be found in this early Japanese matchlock.

fitted with spring-driven wheel locks, possessed of rifling (though still using spherical balls) and fitted with drift-adjustable front blade sights and range-adjustable rear leaf sights (Figure 3). Instead of the more familiar ladder sights (Figure 4), the Renaissance guns used multiple metal leaves, each taller than the next for greater range.

As firearms improved in reliability and accuracy, more complex sights were introduced, with ladder rear sights becoming common after the 1830s, and receiver or tang-mounted peep sights (Figure 5) being introduced after the 1850s. All of these suffered from a major functional limitation: the target and the front sight were not in the same plane of focus. This was not a great problem when engagement ranges were short and a typical shooter had young eyes and enough daylight was available to constrict the pupils, or when the peep sight artificially increased the depth of field of the sight picture. But it was much more of a problem for accuracy in low light, with older shooters, and with butternut, camouflage, or khaki uniforms of the foe

Figure 4: Ladder rear sights allowed the shooter to quickly select a range at longer distances.

Figure 5: A tang sight can be adjusted both for vertical elevation and horizontal deflection.

Figure 6: During the Civil War, units experimented with early types of camouflage, thus making sighting an enemy difficult through small aperture sights.

blending with the environment (Figure 6). The solution, in the form of optical sights, was first developed in the 1840s and tested in combat during the American Civil War.

Early optical sights were fairly similar to the camera lenses of the day. A long focus optical design required long tubes and had severely limited light gathering capacity and field of view. Contemporary records and surviving samples indicate fixed magnification ranging from 3X to about 20X. Reticles were simple crosshairs made of, as the name suggest, hair strands. To simplify the scope design, adjustments were effected externally using elevation and windage screws. While optical sights made the most of rare accurate and powerful rifles such as Sharps and the polygonally bored Whitworth, extending their practical range to about 500 yd., most of the handheld black powder guns were still used at much shorter ranges. So, both cost and expediency kept iron sights preeminent.

Figure 7: An early telescopic design can be found on this 45-70 Sharps rifle.

Development of Modern Sights

All that changed in the 1890s with the successive introduction of smokeless powders, jacketed projectiles, coincidence-based rangefinders, and hydraulic recoil buffers on cannon. Accurate indirect firing became practical while the stresses to which optics, now separated from the recoiling breech, were subjected became greatly reduced. Unlike rifle telescopes made with refractive optics, many of the cannon optical sights were prismatic designs (Figure 8) using a pair of Porro prisms (glass prisms silvered for reflection) to provide an upright, magnified image through a shorter, more compact optic (Figure 9). Smaller size permitted hiding the

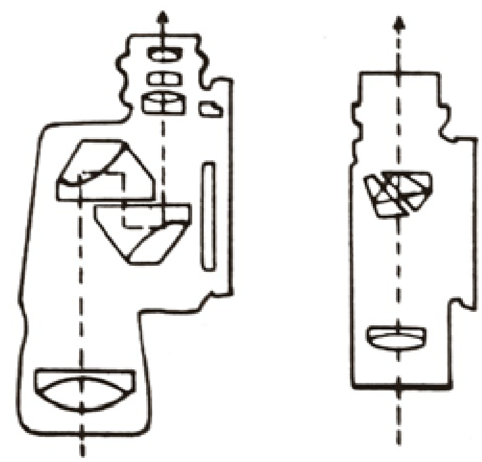

Figure 9: Left: A simpler Porro prism. Right: A more complicated — but also more compact — roof prism.

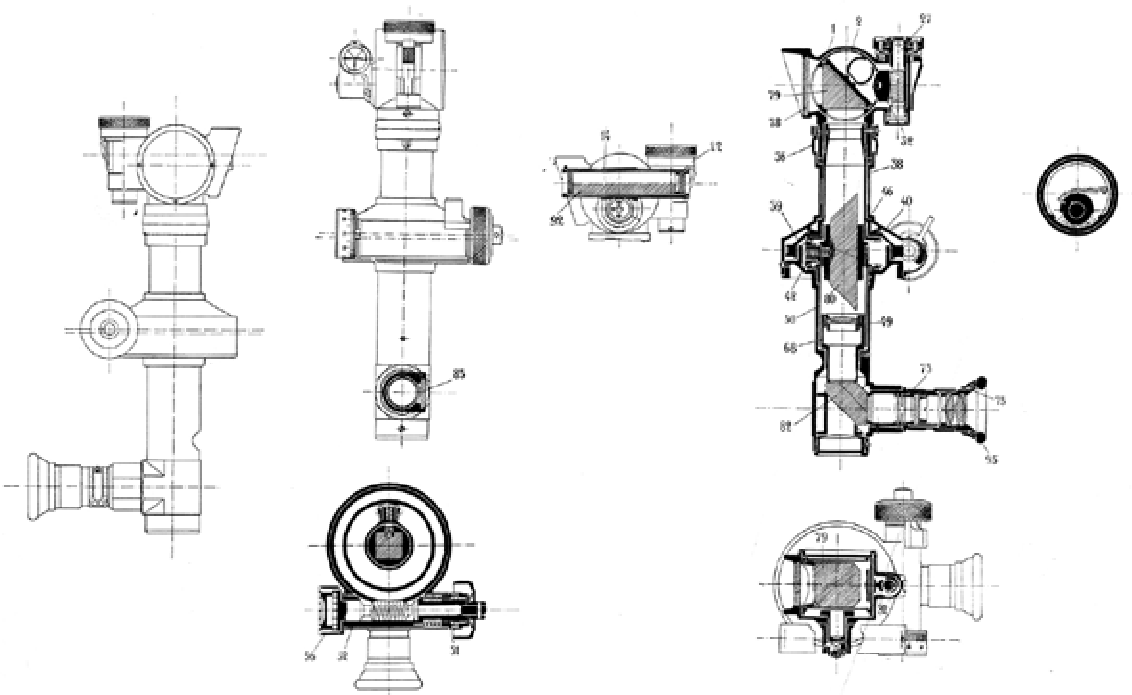

Figure 8: Early cannon optical sights utilized a prismatic design with two Porro prisms.

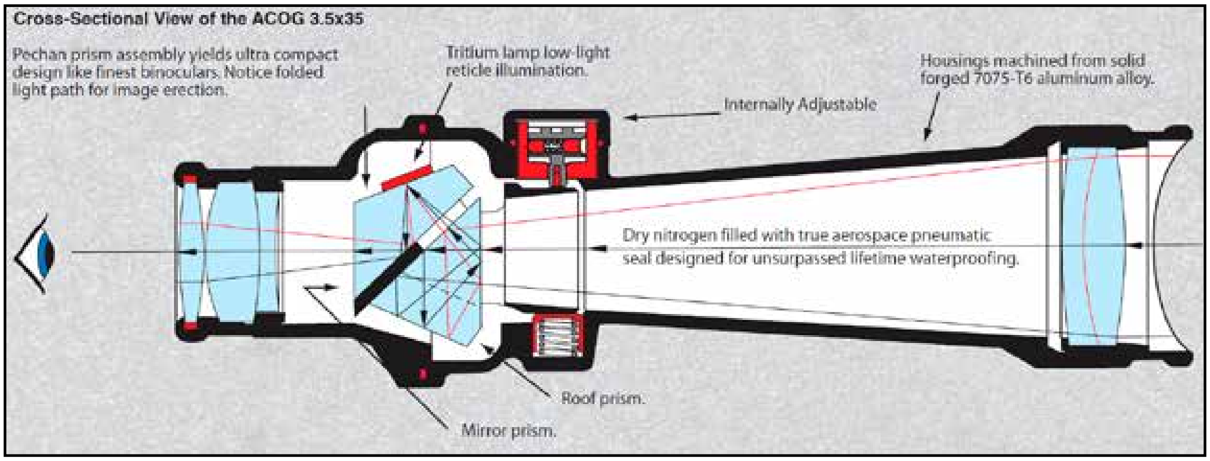

Figure 10: The ACOG sight system.

optics behind gun shields, away from most of the muzzle blast. While surviving samples often look quite dim, that is due in part to the deterioration of the original metallic coatings; the originals worked well when new. Modern prismatic scopes, such as ACOG (Figure 10), use roof prisms. Binoculars and camera viewfinders still use both designs, with Porro prisms reserved for less expensive models. For the same size, Porro prisms can be brighter and are simpler to produce, but they are less space-efficient overall. For clip-fed rifles, an offset form of the

Figure 11: Machine gun vertical offset battle sight.

Porro prism sights permitted unblocked access to the receiver top at the cost of small opticals offset from the bore. For machine guns, a vertical offset (Figure 11) permitted lower, less exposed crew position. While refracting telephoto camera lenses (physically shorter than their focal length) were invented in the mid-1880s, they were not put into use for rifle scopes until the 1920s, and even then only on the high end. The reason for this was the greater precision of production required. Lesser scopes, such as budget rimfire models, retained the inferior long-focus design with the attendant length, poor field of view, and light gathering well into the 1970s.

One of the most severe limitations on scope development was the decrease in contrast as the number of glass elements increased. Invented in the 1890s, anti-reflective coatings on scopes appeared in Germany in the 1930s but were of limited effectiveness. By the 1970s, multicoating combined with a telephoto lens design made bright scopes with a wide field of view possible. As the quality of optical designs improved, mainly by the availability of computers for calculating the effects of aspherical lenses and variable magnification, zoom optics became more common (Figure 12).

Figure 12: The Unertl scope became the de facto U.S. Army and Marine Corps standard for combat optics during WWII.

Figure 13: A Vietnam era starlight scope mounted on an M16A1 rifle.

By WWII, American firearms had largely been standardized on a consistent mount: two simple rail nubs on top of the receiver. While workable, the design was neither robust nor very flexible. As clip loading became less important, single-piece mounts bridging the front and the back of the receiver gained popularity. Between greater light gathering of conventional scopes and bulky early "starlight" night optics (Figure 13), much more robust solutions were in use by the time of the Vietnam War. Some of those mounts are still in use on M1A and M14 rifles today. By the mid-1990s, a standardized development of the Weaver mount was adopted widely as the MIL-STD-1913 Picatinny rail (Figure 14). Used for optics and other accessories, it was designed to maximize compatibility with the widest variety of devices. At this time, even the newest Russian small arms conform to that standard.

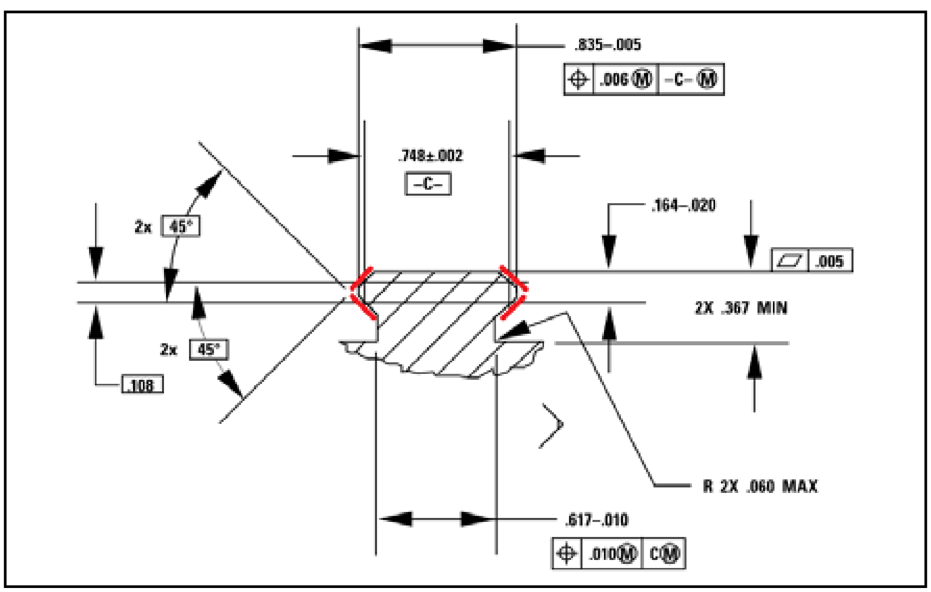

Figure 14: A schematic view of the MIL-STD-1913 Picatinny rail system.

Figure 15: . WWI D5 machine gun sight.

Figure 16: M1 Russian VEPR rifle with Warsaw Pact standard side rail mount.

Figure 17: The Russian AKM pattern rifle utilizes a side-mounted rail so that the optic can be easily viewed above the dust cover.

In parallel with mount developments, more sophisticated reticles appeared. While the first scopes used either simple crosshairs or posts, by WWI the externally adjustable mounts often incorporated range corrections precalculated for the most likely ammunition. By the 1960s, two directions were pursued: precalculated BDC reticles favored by the Warsaw Pact members and slower but more flexible mil-dot or mil-radian reticles more typical of the NATO countries. The latter solution would work with any rifle, caliber, and ammunition, but required individual snipers to develop correction tables for their specific weapons. Designated marksmen in Western armies often got optics, like ACOG, with range-finding and drop-compensating reticles similar to the ComBlock counterparts (Figure 15.)

By World War I, optical sights became common on cannon and machine guns, and standard mounting solutions developed—typically side rails (Figure 16) with various screws or clamps to secure the optics. The current Russian side-mount (Figure 17) used on AK and SVD rifles is a direct descendant of the original circa 1910 mounts. Modern-sounding features, such as the illuminated reticle, was actually with us from the start, all the way back to the 1901 Zeiss prismatic scope. Other advancements, like nitrogen-filled tubes, had to wait for WWII. The same was true of just making scopes that kept a reliable zero: neither British nor U.S. WWI snipers could count on that, and even some of the WWII British optics suffered from zero drift. Since optics were fragile and prone to fogging, iron sights were almost always retained alongside of the glass. You can see open sights on the 1903 Springfield (Figure 18) and peep sights on the Winchester .22 target rifle (Figure 19) mounted along with the 10- or 14-power Unertl scopes. The rimfire rifle shows a recoil-dampening spring (Figure 20) wound around the sight. Upon firing, the scope would slide forward in its mount, compressing the spring.

Figure 18: 1903 Springfield open sights.

Figure 19: Winchester .22 target rifle peep sight.

The shooter would then return the scope into sighting position by hand. Military issue scopes usually lacked that feature because it was judged unreliable. As a result, the scope was subjected to the full brunt of 30-06 recoil. The other issue with the early sights was the field of view: at 100 yd., the scopes shown in Figures 17-19 had a field of view of around 3 ft., while a comparable modern scope at the same magnification would show at least twice as much. Although the hooded front sight is directly in the path of the scope, it is sufficiently out of focus to be invisible during aiming. Modern antireflective attachments like Killflash (Figure 21) work on the same principle.

Figure 20: Mounted Unertl scope with recoil-dampening spring.

Figure 21: A Killflash sight attachment prevents compromising reflections.

Figure 22: The venerable Soviet PU scope is mounted on the side of the Mosin Nagant M91 rifle seen here.

Early to mid-20th century scopes show a variety of design solutions. For example, while most scopes keep the crosshairs centered at all times, the Soviet PU series (Figure 22) moved the reticle instead of the optic, often resulting in a very de-centered zeroing solution. WWII Germany invested heavily into what would later be called "scout" scopes: small magnification optics with very long eye relief. While the Zf41 1.5x designated marksman scope (Figure 23) had the advantage of permitting unobstructed loading and ejection from a variety of rifles, it gave such a poor image as to restrict the shooter performance. With around 100,000 of them made — the greatest wartime production of any optical rifle sight by the German industry — they got used. Even so, captured Soviet optics, primitive as they were, and a wide variety of privately obtained hunting scopes supplemented the official issue. By contrast with this indifferent early effort at equipping DMRs, Germany was the only country other than the U.S. to field

Figure 23: Zf41 scope.

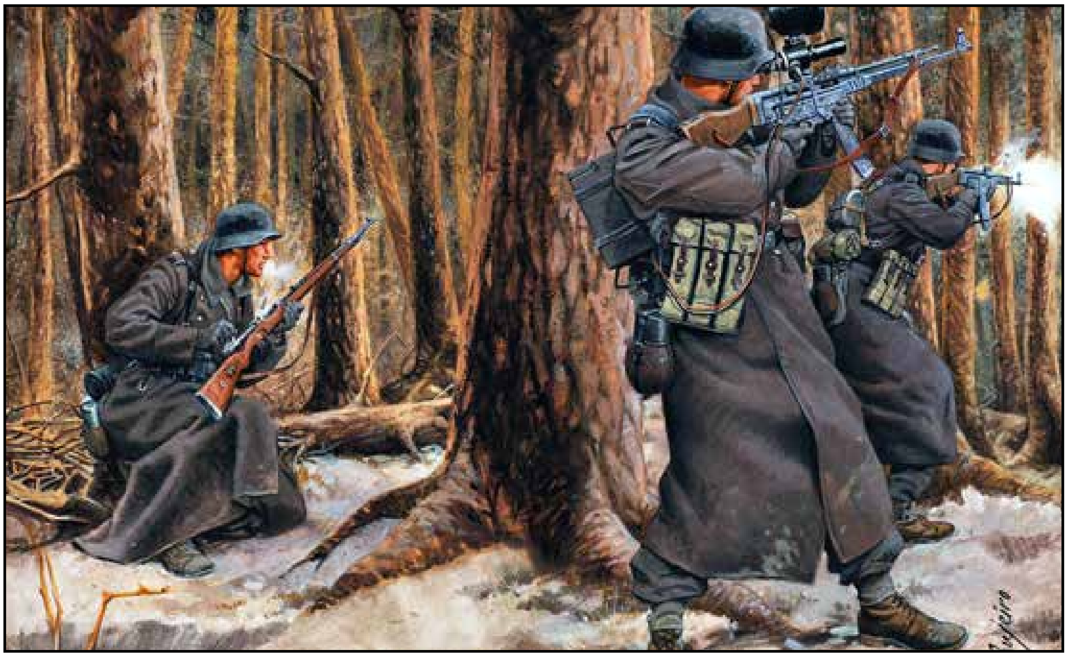

Figure 24: Artist's rendering of the Vampir infrared scope mounted on the STG 44 (seen on the right).

an infrared night scope by 1945. Code-named Vampir and used largely with STG44 automatic rifles (Figure 24), the scope required an infrared illuminator but was effective enough in the absence of similarly equipped opposition. The U.S. Army and Marines used an analogous system with a T3 .30 carbine (Figure 25), primarily to guard against Japanese nighttime infiltrations.

REFLECTOR SIGHTS

Unmagnified reflector sights appeared in the early 1900s and became popular for aircraft use. Unlike scopes, reflector sights (Figure 26) have unlimited eye relief and a very extensive eyebox, the space from which the sight picture can be seen. Comprised of only three glass elements,

Figure 25: The M3 infrared scope was the U.S. military's first night optic design, developed in 1945.

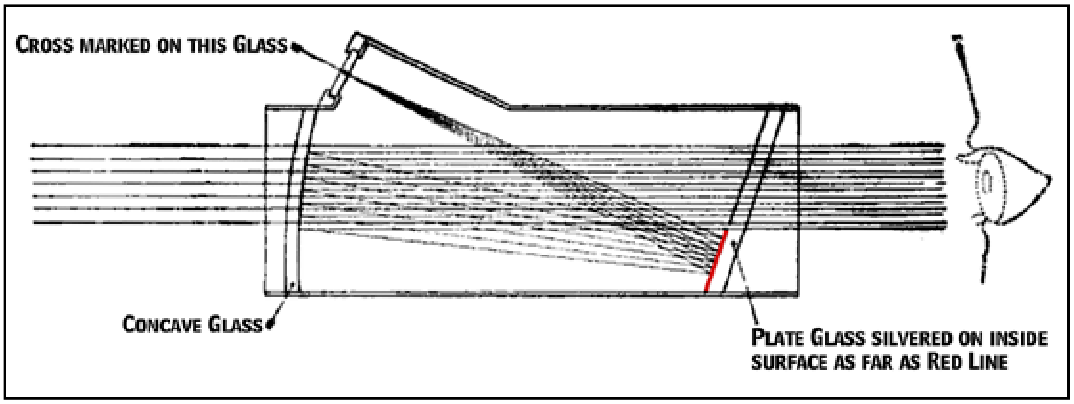

Figure 26: Early design of the unmaginified reflector sight.

Figure 27: Nydar sight mounted onto a Browning A5 shotgun.

two of them stationary, they were quite simple and robust compared to scopes, but their utility was limited by the use of ambient light to create the reticle. On an airplane operating in daylight skies, that worked well enough, but less well on a rifle inside a dugout or a machine gun at night.

Like scopes, reflector sights put the reticle in the same focal plane as the target, or close enough to it. With no magnification, optical "infinity," beyond which neither defocus nor parallax mattered, started closer than 50 yd. The advantage of these sights was in the wide field of view and the ability of the shooter to keep both eyes open. By WWII, most fighter aircraft and some gunners on bombers had this type of sights. Many of the sights, including those on the Spitfire, B17 and B24, had user-adjustable reticles to account for different weapon configuration or target size. The shotgun reflector Nydar 47 sight (Figure 27) came out in 1945, and some were later pressed into service on the Browning Auto 5 and similar semi-automatic trainer shotguns for turret gunners.

Figure 28: OEG sight design made by Armson USA.

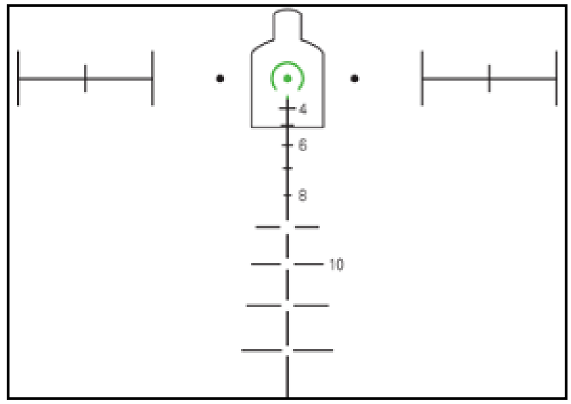

Figure 30: The ACOG reticle appears green when viewed by the shooter.

Eventually, battery and fiber optic versions appeared. The occluded eye sight (OEG) of 1970 was a non-transparent tube with a dot reticle facing the shooter's eye (Figure 28). One eye saw the target, the other saw the reticle, and the mind composited the two for an approximate sight picture. By the early 1980s, the ambient illumination was supplemented with tritium for dusk. Similarly, battery-operated red dot sights in the current sense of the word appeared from Aimpoint in 1975 (Figure 29). Battery life and durability continue to improve through today. Both tube style and open "reflex" screen type of red dots (Figure 30) use a tinted projection window with a dot of complimentary color, usually but not always red, emitted by an LED and focused on the glass. Some sights, like the Russian Cobra (Figure 31), support multiple reticles. A third type of reflector sights, exemplified by EOTech (Figure 32), uses a laser

Figure 29: The Aimpoint® Micro™ red dot sight utilizes battery operation for its reticle illumination.

Figure 31: The Russian Cobra sight is side-mounted on to the AK-74M rifle seen here.

to illuminate a hologram through which the shooter aims. The sight picture on such sights is brighter and slightly less distorted, but the battery demands of lasers are higher than that of LEDs, so these units tend to have lower battery life. Such sights also have the advantage of a greatly reduced light signature from the enemy side. A special subset of optics looks like red dot sights but are actually unmagnified prismatic scopes. Like red dots, they allow sighting with both eyes open, but unlike them do not require battery illumination. They can be identified by a tube shape with an untinted front lens. The down side to them is limited eye relief.

Together with scopes, red dot sights freed firearms from dependency on sight radius for precise

Figure 32: The EOTech® sight is considered a "holographic" design, which emits a laser into the shooter's field of view.

aiming. That made short bullpups and ultra-short conventional rifles viable as military weapons. Further miniaturization made red dots viable on pistols, though they are mainly used for sports applications.

Figure 33: A Vortex® optic that features the unmagnified prismatic design is mounted on the IWT® Tavor™.

Figure 34: This competition shooter uses a Vortex red dot design mounted on her Ruger™ Mark III Custom .22 pistol.

NOTES

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Chapter 3 - Metallic Sights: Design and Application

Introduction

Most rifles with iron sights are sighted carefully at the factory by teams of expert target shooters as part of the final inspection. These sharpshooters fire several series of shots at targets, then make any necessary sight adjustments to ensure that the sights are in proper alignment.

However, no two shooters have identical eyesight, and everyone has a different method of sighting a rifle. Even if a rifle fresh from the factory is sighted satisfactorily, the new owner must find his or her proper rear-sight setting to ensure correct high and low shooting at various ranges.

Unfortunately, most shooters do not know how to properly sight a rifle. As a professional gunsmith, you can instruct shooters on any indoor

or outdoor range; that is, you can first get a rifle approximately in line and then look over the shooter's shoulder as he or she fires. This lesson will teach you how to make the proper adjustment for the individual shooter. Once you learn this skill, you can charge from $20 or more per hour for your time. And, in most cases, all the tools you will need to make the adjustments can be carried in your pocket.

Sighting Fundamentals

Rifle sights are manufactured in what appears to the beginner as a bewildering variety. To understand the simplest of sights, you need to know the basic principles of sighting. The two most common sights are the bead front sight and the notched, open rear sight.

In aiming with these sights for target shooting, the top of the bead on the front sight should be held directly at the bottom of the target's bullseye, as shown in Figure 1. The rifle should be held so that the notch in the rear sight is in line with the front sight bead, with the front bead centered in the notch and the top of the bead level with the top of the notch. Experience will enable the shooter to vary elevation, but at the start it is best to adopt a regular way of sighting.

Hunting requires a different sight alignment: either the top of the front sight or the entire bead should be held on the exact spot the bullet is to strike (Figure 2). As long as the shooter is not holding the rifle high to make allowance for range differences (holding high), this method of sight alignment will prove satisfactory.

A peep rear sight, instead of an open sight, gives the shooter a better combination when used with the bead front sight. An open rear sight, when used at long range and in combination with the bead front sight, may hide too much of the target. In any case, a shooter's method of sighting with both types of sights should be uniform.

By knowing the simple details of sighting, a shooter will be able to concentrate more on his or her target or game and increase shooting accuracy.

SIGHT STYLES

If the shooter is using a simple blade front sight in combination with either the peep or open rear sight, the sights should be aligned as described in the instructions previously given, following either the hunting procedure or the target-shooting procedure. If the shooter is using an aperture front sight, also called a hooded front sight (Figure 3), with a peep rear sight (Figure 4), the aperture should "ring" the bullseye in such a way that a thin, white ring shows around the bullseye, as shown in Figure 5.

When using a peep rear sight with a ramp or post front sight, the front sight should be held on the target as described previously, with one exception: now only the front sight is seen, and there is not a notch in the rear sight to align the sight to the target. Because the shooter's eye is

Figure 1: Open rear sight and bead front sight correctly aligned on target.

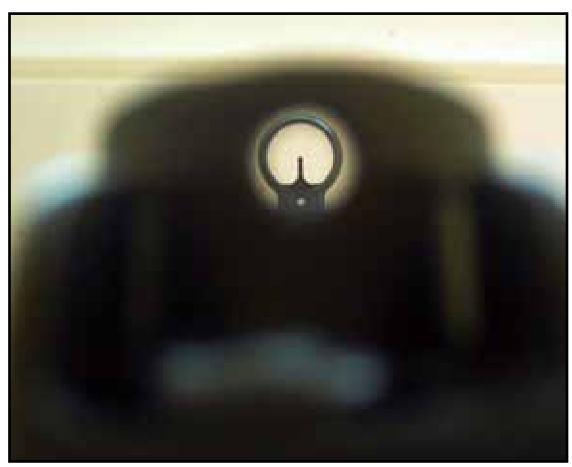

Figure 2: Peep sight of the HK MP5 submachine gun.

Figure 3: Hooded or aperture front sight.

Figure 4: Micrometer receiver target sight, a form of peep rear sight.

so close to the peep sight, he or she will tend to look through the center of the hole (Figure 6). Here again, it is important to establish a firm regular habit of sighting through the rear sight. The eye should always center the top of the front sight in the center opening of the rear sight.

To prevent injury from recoil when shooting a high-powered rifle, do not hold a peep sight too close to your eye. The same precaution applies when using a telescopic sight.

ADJUSTING SIGHTS

Most sights have some means of adjustment for both windage, or sideways movement, and elevation. Most adjustments are made at the rear sight. On some rifle and handgun sights, windage adjustment can be made by moving the rear sight to the right or left in its slot. Use a brass drift punch and a hammer. If your gun is shooting to the right, move the rear sight to the left. Always move the rear sight in the direction you want the shot to go. In rare cases, it may be necessary to move the front sight, too. Always move the front sight in the opposite direction you want the shot to go. To make this adjustment, “zero-in” your rifle for windage. When shooting in the field, you must allow for wind drift by pointing the rifle right or left of the target.

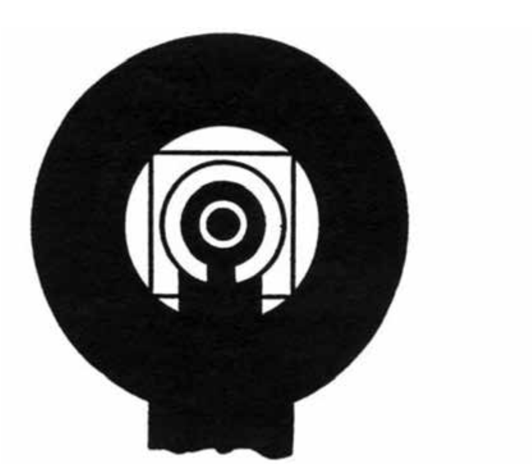

Figure 5: Micrometer, peep rear target and aperture front sight on target.

Figure 6: Peep rear sight and blade front sight aligned on target.

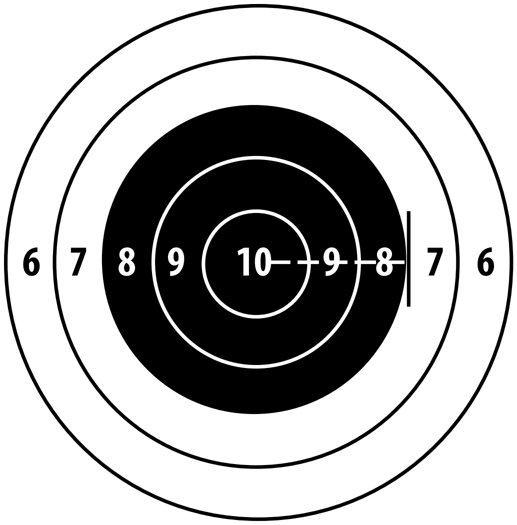

Figure 7: Target showing need for windage adjustment of sights.

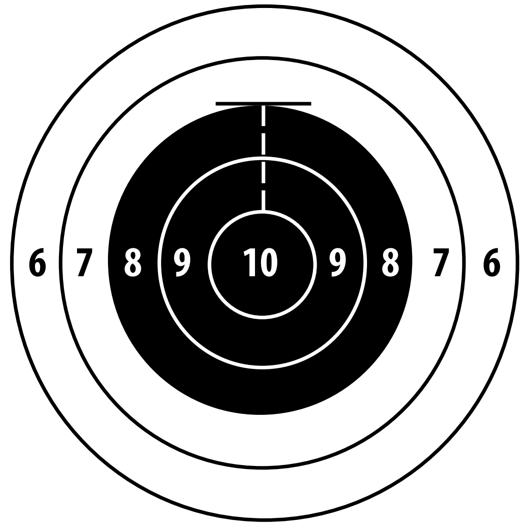

Figure 8: Target showing need for elevation adjustment of sights.

On the ordinary open rear sight, elevation adjustments are made by means of a notched slide, or elevator, moving forward or backward in line with the barrel. Remember that raising the rear sight raises the point of impact of the bullet on the target. The notches on the elevator provide the simplest form of indicator scale for elevation. For example, if the shooter finds that for correct elevation in shooting at 100 yd., the rear sight must be set in the second notch of the sight's elevator, that notch becomes the 100-yd. notch.

Peep sights are equipped with an elevator scale and are raised or lowered by means of either a screw or a slide and clamp. After zeroing, or sighting, at the desired range, the shooter notes the reading on the elevator scale. This becomes the rifle's zero for that range.

MICROMETER ADJUSTMENT

Most aperture or peep rear sights and all telescopic sights have a micrometer caliper graduated in ¼-, ½-, or full-minute divisions. A change in elevation or windage of 1 minute, or $1/60°$, will move the point of impact of the bullet 1 in. at 100 yd., 2 in. at 200 yd., 3 in. at 300 yd., and so on. For a ¼-minute change, one click will move the bullet ¼ in. for each 100 yd. of range. With this precise method of changing sights, it is easy to get an exact adjustment.

First, fire a group of at least three shots. Determine the center of this group and measure the distance in inches from this center to the center of your target (for example, 6 in.). Divide each distance in inches by the range in hundreds of yards (for example, 200) to get the number of minutes change in sight needed (6/2 =3). Move the rear sight the proper number of divisions in the direction you want the shot to go. Figure 7 illustrates lateral movement, or windage; Figure 8 illustrates elevation. If your sight is graduated in ¼-minutes, you will need four times as many clicks as you have minutes (3 x 4 = 12 clicks).

In many cases, both windage and elevation will be off. When this is the case, measure the vertical distance from the center of the group to the vertical centerline of the target to determine the elevation change.

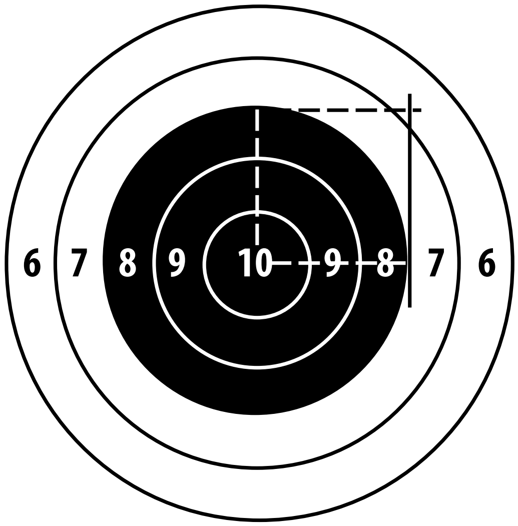

Figure 9: Target showing need for both elevation and windage sight adjustments.

Measure the horizontal distance from the center of the group to the horizontal centerline of the target to determine the change in windage. This is shown in Figure 9.

After changing sights, it is a good idea to fire another group of three to five shots to verify your settings.

Most hunting telescopes have interior adjustments for sighting. Knobs or screws are provided for changing adjustment and are marked Right or Left, Up or Down. Divisions are usually in minutes. Target telescopes have exterior adjustments in the mounts, with thimble and barrel calibrations similar to those on the micrometer caliper. Divisions are ¼ or sometimes ⅛ minute, with an audible click marking each division.

SIGHT-SETTING CHARTS

Suppose your gun is sighted at one range, but you want to shoot at a longer or shorter range. You can do this by holding high or low the proper amount on your target or by adjusting the sights.

The path, or trajectory, of a bullet is given in terms of the average drop in inches of the bullet from the horizontal line of the rifle bore at various ranges. While these values are only absolutely correct when the bore of the rifle is perfectly horizontal, for all practical purposes the ballistic data can be used at angles of up to 10° from the horizontal.

Drop values, as stated in ballistic or bullet-drop tables, are based on information from individual cartridges, and such information is helpful in comparing various types of cartridges. However, hunters and target shooters are more concerned with how this trajectory data can be applied to their sighting problems, so the simple calculation necessary is discussed and outlined below.

The drop values quoted in most ballistic tables are related to the line of bore or, more correctly, to the initial line of travel of the bullet, but the shooter aligns his or her rifle by use of the sights. The difference between the line of sight before firing and the initial line of travel of the bullet is complicated by the jump and recoil of the rifle. Consequently, the shooter adjusts the sights by trial and error to be correct at one fixed range. Having done this, the shooter needs to know the sighting error at other ranges in order to aim high or low accordingly.

Refer to Figure 10 and the following equation to see how to calculate sighting errors.

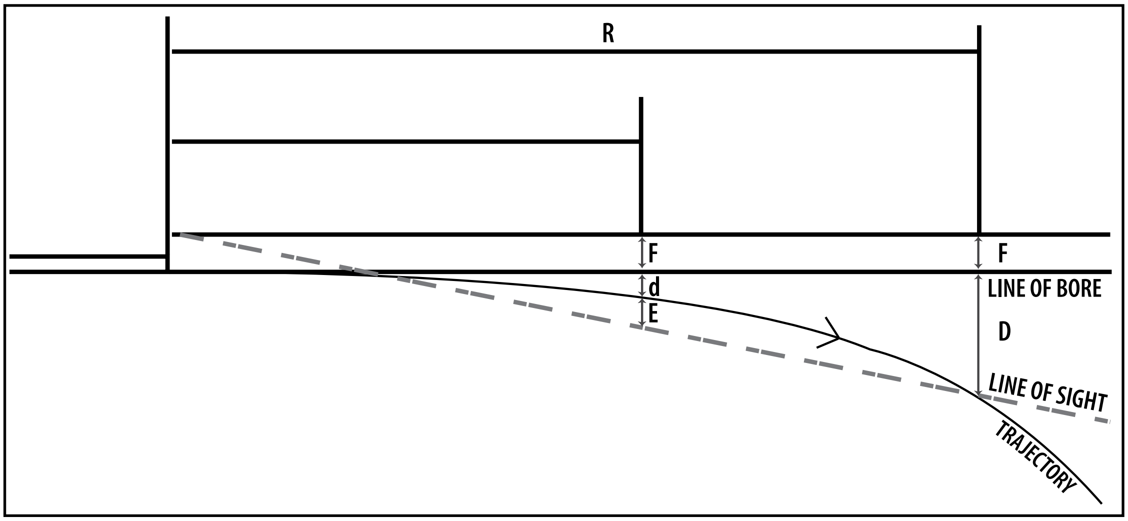

Figure 10: Illustration showing a bullet's trajectory in relation to the line of bore.

E = r(D + F)/R–(d + F)

Where:

R = the range in yards at which the rifle has been correctly sighted.

r = the range in yards in which the sighting error is required.

F = the height of the front sight (or axis of a telescopic sight) above the bore axis in inches.

D = the drop of the trajectory in inches at the range chosen for zero sighting error at the range R.

d = the drop of the trajectory in inches at the range r.

E = sighting error in inches.

If E is positive, then the trajectory at the range r is above the line of sight; to correct this, the shooter should aim low. If E is negative, then the shooter should aim high. For example, if a rifle with a front sight 1 in. above the axis of the bore has been sighted to give 0 error with a .22 caliber Long Rifle cartridge at a range of 100 yd., how much should the shooter aim high or low at a target at 50 yd.?

To solve the problem, refer to the ballistic chart in Figure 11, then proceed as follows:

R = 100 yd. and F = 1”

D (from the data in Figure 11) = 11.2”
r = 50 yd., d (Figure 11) = 2.5”

E = r(D + F)/R-(d + F)

= 50(11.2 + 1)/100 -(2.5 + 1)

= 50x 12.2/100-3.5

= 12.2/2- 3.5

= 6.1-3.5

= +2.6

E = 2.6”

Thus, for a target at 50 yd., with the rifle sighted at 100 yd., the shooter should aim 2.6 in. lower for the bullet to strike the target.

Description	Bullet Weight (grams)	Velocity (ft./sec.)							Energy (ft. lb.)							Drop (in.)					
		Muzzle	25 yd.	50 yd.	75 yd.	100 yd.	150 yd.	200 yd.	Muzzle	25 yd.	50 yd.	75 yd.	100 yd.	150 yd.	200 yd.	25 yd.	50 yd.	75 yd.	100 yd.	150 yd.	200 yd.
22" Long Rifle High Velocity	40	1375	1280	1195	1130	1075	1000	935	168	145	126	113	103	88	77	0-6	2-5	6-0	11-2	27	52
22" Long Rifle High Velocity	35	1375	1260	1170	1095	1045	965	890	147	124	106	93	84	72	62	0-6	2-6	6-2	11-5	28	55
22" Long Rifle Target	40	1100	1055	1015	980	950	890	840	107	99	92	86	80	71	63	0-9	3-8	8-8	16-0	38	71
22" Long Rifle Standard	40	1050	1015	980	945	915	865	—	98	91	85	80	75	66	—	1-0	4-1	9-5	17-4	41	—
22" Long Rifle Standard Hollow	35	1050	1005	965	930	895	835	—	86	79	73	67	62	54	—	1-0	4-2	9-7	17-7	42	—
22" Short High Velocity	30	1125	1050	990	935	—	—	—	84	73	65	58	—	—	—	0-9	3-8	8-9	—	—	—
22" Short Standard	30	950	900	860	820	—	—	—	60	54	49	45	—	—	—	1-3	5-2	12-0	—	—	—

Figure 11: Ballistic chart of one brand of rimfire ammunition.

Now let us assume that the shooter desires to hit a target at 150 yd.

$r = 150$ yd.; D (from Figure 11) = 27”

$E = 150(11.2 + 1)/100 - (27 + 1)$

$= 3 \times 12.2 / 2 - 28$

$= 18.3 - 28$

$= -9.7$

$E = -9.7”$

Thus, for a target at 150 yd., with the rifle sighted at 100 yd., the shooter should aim 9.7 in. high.

It is important to remember that the 0 error setting must be carried out with the actual cartridge and bullet types to be used. It is not sufficient to sight with cartridges having a different bullet weight or different muzzle velocity.

Due to the differences among rifles in barrel length, recoil, and other factors, the calculated sighting errors should be regarded as approximate average results which may differ from actual practice.

The rifle sighting table in Figure 12 will help determine the proper amount of change to make for various ranges with all of the standard center-fire cartridges. Remember, these figures are only approximate. Different guns, due to differences in barrel length, barrel weight, amount

Cartridge	Bullet Weight	Type	Path of Bullet Above or Below Line of Sight in Inches					
			50 yds.	100 yds.	200 yds.	300 yds.	400 yds.	500 yds.
.222 Rem.	50	S.P.	+.0.5	+	-4.9	-17.50		
.222 Rem.	50	S.P.		+2.45	+	-10.15	-32.3	-73.8
.22-250	55	S.P.						
.223 Rem.	55	S.P.		+1.9	+	-8.5	-26.7	-59.6
.270 Win.	100	S.P.	+0.4	+	-3.4	-11.5	-25.0	-46.0
.270 Win.	130	H.P.	+0.5	+	-4.2	-13.8	-29.4	-52.5
.270 Win	150	S.P.	+0.7	+	-6.2	-19.8	-43.4	-80.0
.270 Win	150	S.P.		+3.0		-10.5	-31.0	-64.5
7 x 57 m/m	175	S.P.	+0.8	+	-7.3	-24.2		
.30-30	170	S.P.	+1.2	+	-9.1	-31.4		
.30-06	150	S.P.	+0.6	+	-5.2	-17.2	-38.1	-71.0
.30-06	180	S.P.	+0.07	+	-6.5	-21.0	-47.0	-87.0
.30-06	180	S.P.		+3.1	+	-11.3	-34.0	-70.8
.30-06	220	S.P.	+0.8	+	-7.6	-25.4	-54.7	-101.0

Figure 12: Table showing the bullet drop of several popular centerfire cartridges.

of wear, and other factors, may show somewhat different results in actual usage.

These tables are based on centerfire rifles sighted at 100 and 200 yd. These figures show the distance in inches above or below the line of sight. Positions above the line of sight are indicated by a plus sign; those below the line of sight are indicated by a minus sign. Hold under the amount indicated by a plus sign, over the amount indicated by the minus sign, or make the corresponding sight corrections.

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Development of Metallic Sights

Perhaps the most useful item in connection with the rifle is the sighting equipment. Without sights, even the finest rifle would be virtually useless. The average shooter pays too little attention to sighting equipment. The target shooter knows that sights can add or subtract many points from a score. While each expert has his or her individual ideas, all know what type of sight will perform best with their individual eyesight and method of handling a rifle.

The idea of sights is not new; it dates back over 500 years. The open, or regular V-type, sights were used on the earliest muzzleloading rifles — wheel locks, flint- locks, and even the earliest matchlocks.

The earliest guns were smoothbore, using a round ball. Not very accurate, they shot in the general direction the shooter aimed. Then came rifling, which gave the shooter a reasonable amount of control over the gun and where it shot. However, there was no value in this control without a better method of aiming. Consequently, sights were introduced.

Sights were used on guns dating back to 1475. However, the first official recognition of gun sights by an army dates to 1598, when Maurice of Orange ordered that the army of the Netherlands be equipped with muskets having sights.

Modern sights are grouped into two general categories: iron or metallic, and telescopic.

In the past, a wide variety of hunting sights were used. Some were streamlined, while others were very crude. The original hunting sight was probably a simple brass bead similar to that used in all low-priced shotguns today.

Various materials have been used for front sights. The Lyman factory introduced an ivory bead front sight in the late 1870s. Another material often used was "German silver," which was simply an alloy of copper and nickel similar to the metal used in the U.S. five-cent piece.

Next came the so-called "gold" bead. There have been gold beads manufactured from real gold, but most gold beads are actually bronze. Most silver beads are made from various white metals, although there have been sights made from pure silver. Of course, almost any color imaginable can be made today. A bakelite-type substance is used for many types of sights and comes in a variety of colors, including red.

While the choice of a front sight for hunting is more or less a matter of personal choice, the type of hunting to be done greatly influences this choice. For woods hunting, where the background will be green or brown, a white bead of ivory or some ivory substitute is a good choice. A gold bead is also a good choice.

Red beads are gaining in popularity every day. They stand out against a woody green background, against the gray found in hardwood territory in the late fall, against the brown of fallen leaves, and against snow. Many shooters now prefer the red bead front sight for all types of hunting.

Beads come in various shapes, including square and round, and an almost unlimited variety of sizes. While there is a great difference in opinion as to which may be best—the square or round bead—square beads usually yield better results. They are just as visible as round beads and can also be used for target shooting.

Bead size is another factor to consider when choosing the proper sight for a rifle. The choice of a bead size is not only a matter of taste, but also of shooting conditions. For the hunter who does a lot of quick, short-range shooting in poor

Rifle Sight Bead **Revolver Sight Beads** **Shotgun Fiber Optic Bead**

Figure 13: Several types of bead front sights.

light, a large bead front sight, either round or square, is a good choice, because it is easy to see.

For shooting at longer ranges—at 100 yd. or greater—a small bead is best, since it does not obscure as much of the target. A ⅒ in. bead on a 24 in. barrel will completely cover the vital portions of a deer at 200 yd. A smaller bead should be used for such shooting.

However, when considering bead size you need to realize that beads of the same size may look different, depending on what type of gun they are used on. A ⅒ in. bead on a 30 in. .30-40 Krag barrel looks a great deal smaller than that same bead on a Winchester Model 94 20 in. carbine.

Another important factor to consider when choosing a front sight for hunting is the type of bead face (Figure 13). Beads are manufactured with oval faces, slightly rounded faces, hemispherical faces, and true flat faces. Many shooters prefer the flat face because any sight with a curved-face surface is inclined to create errors in aim. For example, if you are shooting in normal daylight, with the sun practically overhead at noon, the top portion of the bead will reflect the rays of the sun, and you will unconsciously use this bright spot when you aim. This will cause you to aim as if you were using a higher front sight, causing the shot to strike low at a normal range.

If the sun strikes the left side of the sight and is reflected from that point, the normal error of aim will cause the shot to strike to the right and vice versa.

These facts are extremely important for hunters shooting in the woods. Hunters searching for big game do not get many shots at their quarry. In many cases, a missed shot may be the only shot the hunter will get during the hunting trip. Accordingly, the hunter should not be handicapped with sights that reflect light, causing an optical illusion. The flat-surface front sight will not reflect light.

Figure 14: This detachable front sight hood is designed specifically for protecting the front sight.

Figure 15: Many front sights are mounted by means of a dovetail slot.

SIGHT HOODS

Aside from sight beads, one of the most useful accessories on a front sight for hunting is a detachable hood (Figure 14). These hoods should not be used in the woods or fields; they should be detached and carried in the hunter's pocket. A hood will protect the corners of the sight from being knocked off if the gun is bumped during normal handling or while in the gun case.

Most of the better centerfire rifles produced over the past 50 years or so have these detachable metal hoods. The rifle can be used with the hood, but most hunters obtain a better view with the hood off. The hood should always be replaced each time the gun is returned to its case. It only takes a minor blow on a front sight to break off the bead or to bend the sight beyond repair. A bent front sight should never be straightened; replace it as soon as possible.

MOUNTING METALLIC SIGHTS

Front sights are attached to rifle barrels in several ways. The simplest way is by means of a dovetail slot in the barrel with the sight driven in. This dovetail is tapered, and the sight should always be driven in from left to right and driven out from right to left, if you are viewing the sight from the breech end. Keep this in mind or you might damage both the sight and the dovetail slot (Figure 15).

Another method of mounting a sight to the rifle barrel is to install a sight ramp or sight base by means of threaded screws or by soldering. However, the blades themselves usually are attached in the dovetail slot on the base. Some have a setscrew to further secure the sight blade.

REAR SIGHTS

There are two distinct forms of rear sights used for hunting — the open sight and the peep sight. We will discuss open sights first. See Figure 16 for a few examples of open rear sights.

The open sight, invariably located on the rear of the barrel just ahead of the receiver, is the most popular form of metallic sight. It is made in two varieties: adjustable and nonadjustable. Every hunting rifle uses an adjustable form of sight. Some of these rear sights have adjustments for both windage and elevation, while others have adjustments for elevation only. In this latter group, if the shooter needs to adjust for windage, he or she must move the rear sight in the dovetail slot in the barrel.

The open sight is the least accurate of the two, but it does have some good points. In the hands of the experienced shooter who must shoot running game in heavy cover, the open sight

Figure 16:U-notch and V-notch open rear sights for use on rifles.

performs nicely. Shooting of this nature is frequently a case of pointing the rifle rather than actually aiming, particularly at short range.

Rear sight notches consist of V types and U types (Figure 16). One of the best rear sight notches for snap shooting is absolutely flat on the top with a small, vertical white line in the center. The bead front sight is merely leveled off even with the top of the rear sight and centered by means of that white line. In the hands of an expert hunter, this is not only a fast means of aiming, but also an unobstructed view of the game. This is particularly important when shooting at moving game.

The U-notch rear sight is designed for use with a round-bend front sight, and the U-notch should be big enough so that just a faint trace of white light is seen on either side of the bead. This permits easy centering. If this U-notch is too small, and the entire bead does not show up properly, shooting will be inaccurate.

V-notches consist of fairly deep, narrow Vs and wide, shallow Vs. For snap shooting, the wide, shallow V is the one to choose. A V-notch should always be used with a round bead sight if the best results from the rear sight are to be obtained.

One type of sight, introduced around the turn of the century, is the buckhorn rear sight. This type of sight uses both V-notches and U-notches. It has a very large U-notch frequently in the form of a half-circle ¼ in. or ⅜ in. wide. In the bottom of this deep U is a small U or V-notch. The existence of these buckhorn sights has never really been explained, since they offer nothing of value to sighting with metallic sights.

A better rear sight is the adjustable folding leaf sight, in which one or more leaves of different types are used. Many hunters assume that this type of sight is fairly new, but folding leaf sights have been around since the 1500s. In practice, each folding leaf has a different sighting range; that is, the first leaf may be for shooting at 100 yd., the second for shooting at 200 yd., and the third for shooting at 300 yd. This type of sight is frequently used on safari-type rifles used to shoot big game.

There are also numerous types of military sights that are located on the barrel with leaves that can be folded up and adjusted either by means of a micrometer screw or by sliding the rear notch. This type of sight is useless for practical hunting purposes and, therefore, will not be discussed in this lesson.

PEEP SIGHTS

Peep sights fall into two distinct groups: those used for hunting and those used for target shooting. Some peep sights used for target shooting are also ideal for hunting, but others would be a handicap in the woods. In addition, there are three different types of hunting and target peep sights: the receiver type; the bolt, or sleeve, type; and the tang type. Of these three, the receiver peep sight is most widely used on hunting and target rifles.

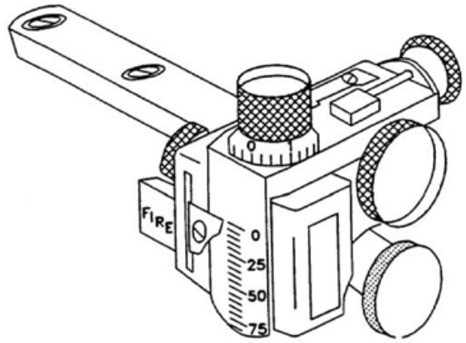

Figure 17: Micrometer adjustment on a typical peep sight.

Contrary to popular belief, the peep sight is easier to use than the conventional open sight, because you do not really use the rear sight. You look through it and merely line up the front sight with the target. To demonstrate, form the thumb and first finger of one hand into a circle. Look at an object across the room, preferably something quite small. Hold the ring (circle formed with the thumb and finger) in front of your eye with your gaze concentrated on the distant object, not your hand. You will discover very quickly that you are looking through the ring, not at it. Shorten the focus of your gaze to concentrate on your hands and you will find that you have your "target" in the exact center of the ring or peep. In other words, your eye centered the object automatically.

The principle is optical. Your eye will seek the center of the peephole without any effort on your part. This is the secret of peep sight use.

One of the reasons why the peep sight is more accurate is that the eye finds it necessary to focus on just two points — the front sight and the target. The experienced shooter lets the front sight go slightly out of focus and concentrates entirely on the target. By doing so, the shooter gets a quick, unobstructed view, and will line the sights practically by instinct. This allows for extremely fast shooting.

Another reason the peep sight is more accurate than the conventional metallic sight is that the distance from the rear peep sight to the front sight is longer; the longer the distance between sights, the less margin of error.

For hunting, as well as for target shooting, the peep sight should be located as close to the eye as the design of the mechanism and sight will permit. In most cases, the receiver peep sight is located on either the left or right side of the receiver. Some rifles offer a choice of mounting on either side, even in the same make and model of rifle. The left side is usually the best choice, since, for most right-handed shooters, the receiver sight located on the right would be in the way in rapid-fire manipulation of the bolt handle.

A peep sight offers a great deal of advantage for hunting because there is no ordinary barrel-type rear sight to obstruct the shooter's view of the game. The muzzle of the barrel appears to stick up into the air, and the shooter can see around, above, and practically below the game being shot at. This is particularly important when shooting at running game.

Peep Sight Adjustment. The peep sight may be micrometer adjusted (Figure 17) or equipped with crude, simple forms of moving the rear sight to compensate for various changes in range. Some peep sights have adjustments for both elevation and windage, while others have adjustments for elevation alone. One type of peep sight, used on the first U.S. M1 carbines, used a flip-type adjustment. Consequently, the sight could be changed instantaneously from one sighting range to another. However, for practical purposes the average hunter would do well to sight his or her rifle in at any reasonable range at which game is expected, and then leave it alone when in the field. Hunters, unless they are skilled target shooters, rarely have the ability to make quick adjustments with any reasonable degree of success.

Figure 18: Globe front sight with removable inserts.

If a rifle shoots high, the peep sight should be lowered accordingly. Conversely, if it shoots low, the rear peep sight must be raised. Windage adjustments are made in a similar fashion; that is, if the rifle shoots to the right of the target, the peep sight should be moved to the left; if it shoots to the left, the sight should be moved to the right.

Hunting sights should have adjustments which, once made, can be tightened securely to prevent them from being changed accidentally if the rifle is jostled.

TARGET SIGHTS

A variety of target sights have been manufactured over the years, and new ones are constantly being developed. Let us look once again at the front sight.

Most target sights in use today are blade, or post, sights, which use no form of bead. The round bead is extremely difficult to use for serious target work, and no expert sharpshooter would consider using it.

The simplest form of target front sight is the military blade consisting of a flip-top post of uniform width from top to bottom, either shaded with a hood or used naked. For best results, the target shooter invariably blackens this blade before shooting with some form of smoke or liquid blacking material designed to give a soft, dull-black finish. This keeps the blade from reflecting light and makes it stand out as a perfect silhouette. Target shooters should be extremely careful about using blades with chipped, bent, or worn corners. Most target shooters protect their sight blades and frequently carry spares in case of damage.

Next comes the globe sight. Dating back over 100 years, this sight is by no means new. The most common globe sights have removable inserts with different faces, as shown in Figure 18.

The chief advantage of using one of these globe sights with inserts is that the inserts can be changed to meet existing conditions. Where an aperture or peep front sight is used, this aperture should just encircle the bullseye with a faint white ring around the edges. It is therefore necessary to change the inserts when shooting at various ranges if satisfactory results are to be obtained.

The same is true of changing the post inserts. For short-range targets, a thick post can be used; for long-range targets, the post should be narrowed down as much as possible. Changing the inserts in globe sights usually takes less than a minute.

One main advantage of the globe front sight is that, regardless of the angle of shooting and the direction of the sun, the part that actually serves as the sighting point is well shaded. This prevents any change in point of impact due to an optical illusion.

The most useful target rear sights are usually peep sights. There are two general types of receiver sights: the *standard type* and the *extension type*. The latter has an arm of some sort extending the peep sight as close to the eye as possible. Some of these are nonadjustable; others permit positioning to meet individual requirements. The latter type is useful when shooting

in different positions. It can be extended further to the rear for offhand work and moved up for shooting in the prone position.

For serious shooters, the target peep rear sight has very definite requirements. First, it must have some sort of eyecup so that different sizes of apertures can be used. Second, it must be micrometer adjustable for both elevation and windage. (Figure 19).

Generally speaking, any sight with a micrometer adjustment adjusts by means of a screw thread. The following explanation will seem elementary to the advanced shooter, but it is a good idea for beginners to understand the principle.

Assume that you are adjusting for elevation. Different screw threads are used for easy calculations. Suppose the thread is very fine, running 50 threads per inch. The elevation screw is given one complete revolution, and the sight, therefore, is elevated $^1/_{50}$ of an inch. If given one-half revolution, the elevation is $^1/_{100}$ of an inch or .010 in. . The shooter does not have to figure this out. Various target sights are figured out into minutes of angle.

A minute of angle equals 1 in. at 100 yd. and 2 in. at 200 yd. If a sight is graduated thus, the makers advise the buyer that with the sight mounted

Figure 19: Target receiver sights with positive-click, micrometer adjustments on both windage and elevation.

properly, the shooter will have ¼-minutes of angle of adjustment. This means that the shooter can change the sights in elevation or windage by such a minor degree that it will represent only ¼ in. in impact at 100 yd. This is extremely important for precision shooting. In small-bore work at 25 yd. or at 50 ft. the expert shot frequently has to change his or her sights enough to move the point of impact of the bullet over by less than the width of the bullet to make perfect scores. Too great a movement would place the shooter on the opposite side of the bullseye.

A click-adjustment rear sight is one in which the various adjustments are made through an attachment to the screw thread, which gives a distinct click, usually in ½-minute and ¼-minute increments.

Bear in mind that when adjustments are in the rear sight, you must always move the rear sight in the direction that you want your shot to move.

Assume that the shooter is capable of fine shooting and desires to sight-in his or her rifle for shooting at 100 yd. Further assume that a steady wind is causing the shooter some problems. The light on the target changes the appearance of things, and other range problems have come up. Accordingly, the shooter tries two sighting shots, both very carefully aimed with the conventional 6 o'clock hold at the bottom of the bullseye. Let us assume that both shots cut into the same bullet hole at about 7:30 o'clock, 1 in. low and 1 in. to the left.

To get the shots into the bullseye, using a peep sight with ¼-minute click adjustments, rotate the windage knob to move the sight to the right four clicks. This represents one minute of angle. Then turn the elevation knob four clicks to raise the rear sight. The net result puts the remaining shots in the bullseye — provided, of course, proper holding and accurate ammunition is used.

Herein lies the advantage of a micrometer-click rear sight. Accurate adjustments can be obtained very quickly without using large quantities of ammunition by making adjustments using the "trial-and-error" system. Also, the trial-and-error system is never permitted in target shooting matches.

With an adjustable sight, the shooter can place his or her shots properly at a different range without wasting ammunition. An accurate log is kept showing what the adjustment should be on the rifle's sight and the micrometer scale.

This whole process may seem complicated, but it really is not. It is the only practical system of sight adjustment when fine adjustments are necessary.

Figure 20: B-Square sight jig is a great help when installing metallic sights .

INSTALLING METALLIC SIGHTS

Most modern metallic sights are designed to be used on a sight base that is attached to the rifle barrel by two or more screws. The next lesson covers complete drilling and tapping operations, so in this lesson we will discuss mainly the tools specifically designed for installing iron or metallic sights.

The B-Square sight drill jig, shown in Figure 20, is excellent for installing both front and rear metallic sights. The jig is based on a precision V-block drill guide with two #31 bushings located .5625 in. apart to match the Williams Guide sights, along with those on Remington and Winchester rifles. The tool can also be used to install shotgun, front bead sights as well as ramp-type sights for rifles. This jig is easy to use and will center one or both holes on any round barrel up to a 1 in. diameter.

Many modern gun shops use a dovetail cutter in a milling machine to cut dovetails in rifle barrels. However, a dovetail can be cut with hand tools. All you need is a small mill file to start the cut in the metal; then use a triangle dovetail file (one cutting side and two safe, or smooth, sides) to finish the dovetail cut.

Custom Sight Installations

Custom sight installations can be addressed in any one of several stages during the production or customization of a firearm. The choice and style of sight, along with the type of firearm, will determine the appropriate time to consider installation. However, if the chosen sighting system involves additional machining, this should be done prior to any final finish.

The style and intended use of the weapon should dictate the type of sight to be used. For example, consider the popular Colt Model 1911 semiautomatic pistol. The recommended sight configuration on a combat weapon is a high-visibility, fixed-sight system. Many are available, and most popular models feature a broad, serrated rear blade with a recessed notch.

Blade enhancements are offered with either a white outline or the European dot system. Some of the available configurations are shown in Figure 21.

NOTE: Color-enhanced sights and inserts offer a quick sight reference at short range under limited light conditions. But this advantage is negated at longer distances when the colored enhancement causes varying sight pictures under changing light conditions. Make your choice accordingly, knowing that this trade-off exists.

Most of these fixed sights do not require additional machine work unless they are of the new generation extended variety. A target-style weapon will require a suitable adjustable sight to accommodate various loads. There are many such sights available, and most require extensive

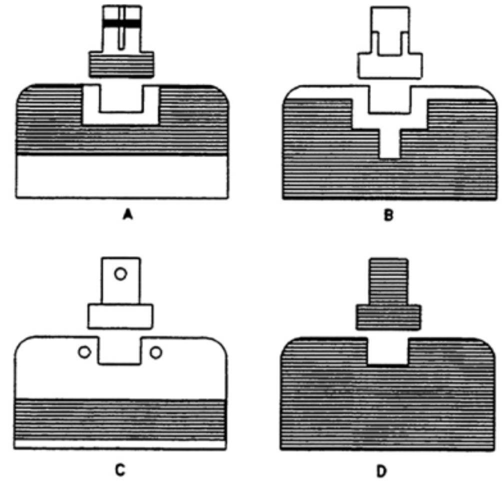

Figure 21: Several types of iron sights for the Colt Model 1911 semi-automatic pistol.

machining. The blade enhancements include both white outline and dot systems. But for the target shooter, the traditional black-on-black configuration is equally as popular (D in Figure 21). The recommended and preferred configuration is the low-profile configuration. This is also the popular choice of combat shooters who prefer an adjustable sight. In the "custom" category, where the shooter's preference is considered more heavily in equipment selection, the chosen sight configurations vary greatly.

NOTE: There are many high-quality custom sights available. However, if your customer indicates a preference for a specific model with which you are unfamiliar, research the product thoroughly before agreeing to install it. Even though the product may be your customer's choice, you are, in essence, endorsing it when you agree to use it. Avoid potential problems involving premature product failure by installing

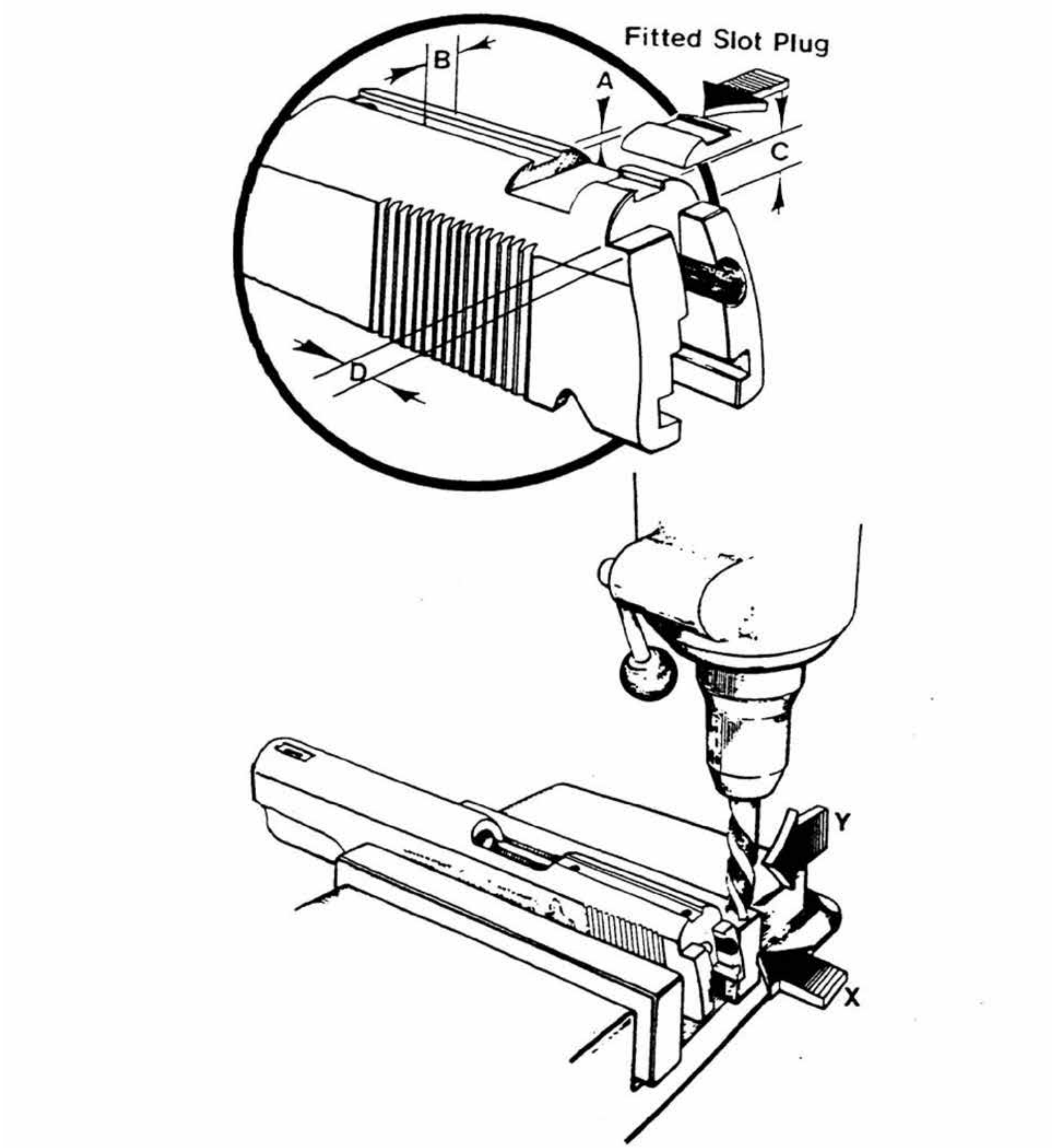

Figure 22: A milling machine with a ¼ in. carbide end mill is ideal for sight modification.

only those components with which you are familiar and willing to endorse. Whatever the chosen sighting system may be, follow the manufacturer's installation recommendations.

Since gunsmiths are still frequently asked to install the S&W K-frame sight on a Colt 1911 semi-automatic, we will address that installation procedure. This adjustable revolver sight was the primary consideration when preforming this popular conversion prior to the availability of specialized custom sights. Because of the nature of this modification, there are no manufacturer's installation instructions available; for that reason, we will outline this procedure.

If the slide being used has been cut for a standard fixed sight, that dovetail must be filled before performing any machining operations. See the close-up in Figure 23. Since the slide has undergone numerous modifications and will require refinishing, this slot-filling method is open to several options. Both swaging and welding are recognized methods. To adhere to our policy of avoiding heat whenever possible, cut a slot blank and fit it carefully to the dovetail. When an interference fit is achieved, press the blank into the slot and peen it in place. Using a mill file, contour the blank to conform to the profile of the slide. Lightly peen the area again to ensure uniform contact. Remove any remaining irregularities by draw filing.

The next stage of this modification is best preformed with a milling machine fitted with a ¼ in. carbide end mill, as shown in Figure 22. The setup requires that the slide be centered and positioned level for a longitudinal pass. Elevate the table to engage the top surface of the slide and make a cut from the hammer recess to the ejection port as indicated by arrow X. This cut (Figure 22 inset) is made to a depth of 0.017 in., dimension A, and then widened to a final dimension of 0.280 in., dimension B. This finished width is achieved by removing 0.015 in.

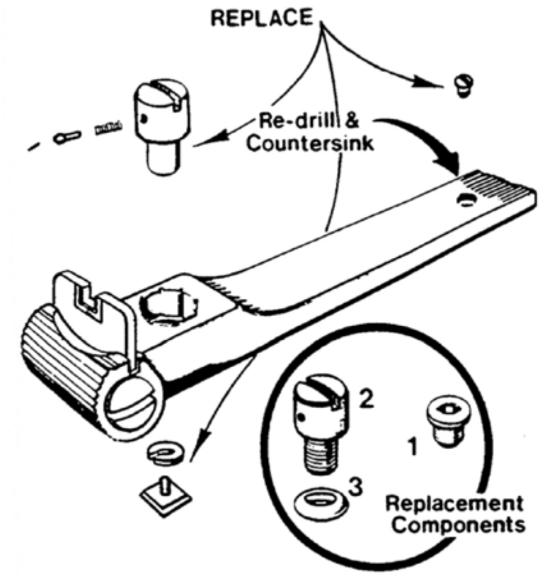

Figure 23: Certain parts are replaced to better handle the shock in the cycle of automatic firing.

from each side of the channel. Next, the end of the slide must be relieved above the hammer to accommodate the sight's windage housing as indicated by arrow Y in Figure 22. This cut can be executed by making several horizontal passes with the cutter set at a depth of 0.175 in., dimension C in Figure 22 inset. Repeat as necessary until a 0.250 in. recess has been cut, dimension D. This completes the required milling procedure on the Colt Model 1911.

Both the front retaining screw and the elevation screw of the new sight will be replaced with heavier and harder screws to better handle the shock in the cycle of the automatic action (Figure 23). The front hole for the retaining screw in the sight tang should be redrilled to a 0.1495 in. diameter with a #25 drill bit.

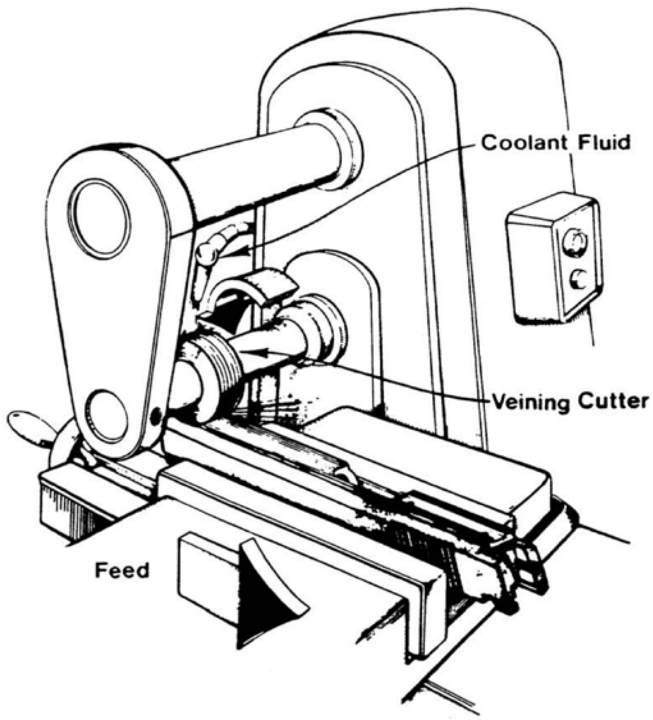

Figure 24: A horizontal mill fitted with a special veining cutter is sometimes used to dress the metal surfaces.

NOTE: Carbide machine tools are recommended when working with the hardened component parts of the sight and slide.

The redrilled hole should then be clearanced with an 82° countersink to accept a #6 flat-head, socket cap screw (#1). The rear adjustment screw should be replaced with a #6 fillister screw fitted with a detent plunger and spring (#2). The head of the fillister may be cross-drilled with a #55 drill bit to accept the detent. The spring and plunger housed in the S&W sight nut can be used. Next, position the sight on the modified slide and mark the location of both holes.

NOTE: The #6 screws are available in several thread dimensions. The recommended threads per inch for both screws is 48, although a lesser tpi is acceptable.

If a 6-48 screw is used, select a #31 tap drill to prepare the slide. Use a #33 drill bit if you intend to tap it 6-40 or a #36 for a 6-32 tap. With the slide properly drilled and deburred, select the appropriate tap to cut the thread. After the threading is completed, clear the taped holes of all chips and residue. Place the sight in position and insert both screws to confirm that you have a full range of adjustment. Remove the sight to shorten and re-dress both the screws and the tang as required.

NOTE: In the final stage of assembly, when you reinstall the sight, place a small rubber o-ring (#3) between the sight and slide and then thread the adjustment screw through it. This will function as a buffer to absorb shock and

prevent the sight from rebounding, a common cause of sight failure.

Before installing the front sight, you may wish to do additional machining to add cosmetic details. Serrating the top of the slide is a popular enhancement and can be accomplished with a veining cutter using multiple passes. An alternate method employs a horizontal mill fitted with a special veining cutter to address the entire surface of the raised rib on a Gold Cup or "custom" slide, as shown in Figure 24.

NOTE: To ensure a fine cut and to protect the cutting tools, the use of coolant fluid is recommended to dissipate heat generated when machining harder metals at high speeds.

The rear slide serration may be best accomplished by hand using a checkering file, as shown in Figure 25. This procedure is initiated by laying out a master line and using each successive cut as a guide. When the grid is laid out completely, the serration may be cut to its final depth with a 60° pointing file. Please note that this operation is completed with the extractor in place so that the pattern is extended over and uniformly covers the extractor base.

NOTE: These special checkering files are available in specific lines-per-inch patterns. For aesthetic appeal, duplicate the pattern used on the rear blade. For example, the S&W K-frame sight exhibits a 30 lpi pattern and is easily duplicated using the appropriate file.

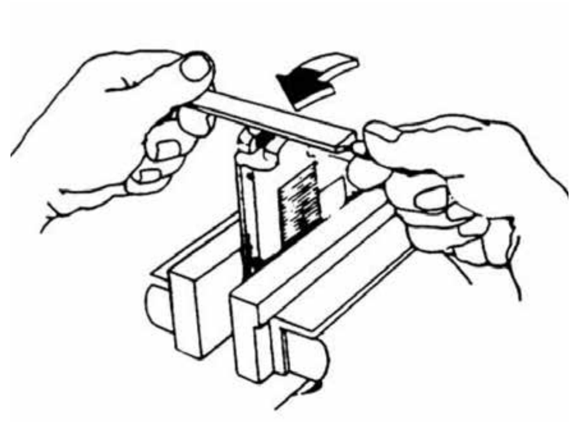

Figure 25: A metal checkering file may be used for most of the serrating operations required to install custom sights on a Colt Model 1911 pistol.

SLIDE PRE-ASSEMBLY PREPARATION

Following basic milling operations, clear the slide of all remaining chips and residue produced by the machine procedures. Check all of the internal machined areas of the slide to ensure that they are blemish-free. (Figure 26). Clear and deburr the channel that houses the firing pin stop indicated by arrow A.

Next, check the firing pin tunnel, indicated by arrow B, to ensure that it is free of obstructions that could interfere with the firing pin spring or obstruct the firing pin movement. If the slide has been in service, inspect the breech face, indicated by arrow C, and remove any existing irregularities. Arrow D shows the extractor tunnel, which must be cleared and deburred before installing the extractor. Finally, the surface of the disconnector rail, indicated by arrow E, should be polished to ensure that it is free of any wear or rub marks.

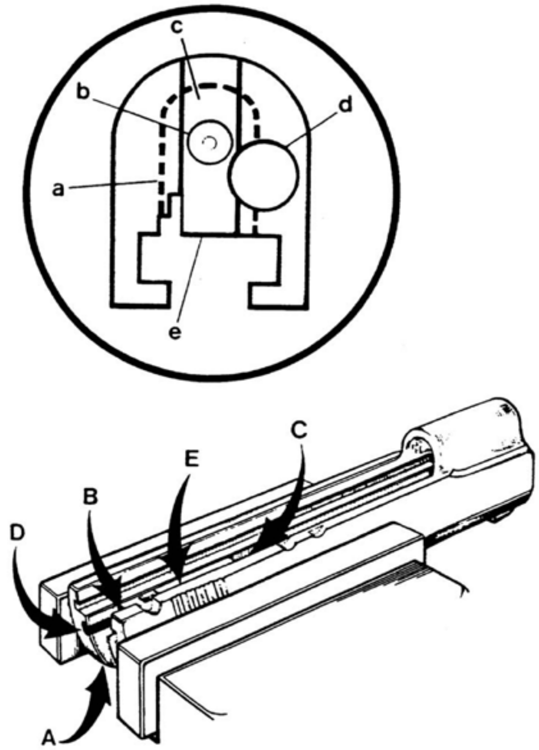

Figure 26: Check all of the internal machined areas of the slide to ensure that they are blemish-free.

Chapter 4 - Telescopic Sights

Introduction

Installing telescopic sights on a rifle can be either easy or difficult, depending upon many factors. Most rifles manufactured after World War II were factory drilled and tapped (or grooved) to accept telescopic sights and mounts; few rifles manufactured prior to World War II had these provisions.

Rifles that have been drilled and tapped at the factory for scope sights are easy to work with, and an amateur should experience little difficulty in doing a good job — provided the project is done in the recommended sequence.

The installation of telescopic sights, or scopes, on rifles that have no factory provisions can be quite a task for both amateurs and professionals. Poor workmanship in this phase of gunsmithing is common. In most cases, poor sight work usually results from trying to align the sight mounts in their correct position by the eye alone, or in marking the location for screw holes by crude and inaccurate methods. This lesson is intended to supply the ground work for the proper methods and principles, which, if adhered to, will always result in a properly installed scope.

Mounting Scope Sights

Mounting scopes on rifles that have been drilled and tapped at the factory is usually a simple job, requiring few tools. Still, certain procedures and precautions should be followed to obtain a good installation that will not fall out of line after a few shots, especially on rifles with a heavy recoil.

Most .22 rimfire rifles—including the .22 Winchester Magnum—have grooved receivers to accommodate scope mounts designed especially for these rifles. Since a slight recoil is experienced with the .22 rimfire, only a firm turn of the mount screws is required to mount a scope securely. Scopes designed for .22 rimfire rifles—such as the Weaver D4 and V22 models—are furnished with mounts at no extra cost, and the installation of these require only the aligning of the mount clips in the receiver groove, tightening the retaining screws by hand, and exerting a final twist with a screwdriver. However, before final tightening, secure the screw clamps so that the scope and mounts will slide in the groove. Then, test the scope for correct eye relief. Once found, tighten as described previously.

Other scopes require mounts to go with the scope sight, the majority of these are ⅞ in. or 1 in. in diameter. These mounts and rings are designed especially for grooved receivers on .22 rifles so the mounting seldom poses any problem.

Scope mounts for .22 rimfire rifles normally use universal clamps that fit into the factory-grooved receivers, centerfire rifles are different. With only a few exceptions, receivers on centerfire rifles are drilled and tapped for specific bases and mounts.

Figure 1: Typical two-piece scope mounts.

The most popular scope bases are those manufactured by Weaver and Redfield. Depending on the rifle to be used, the Weaver mounts can either be a single base or a two-piece base, as shown in Figure 1. Other companies offer the same combination.

To select the proper base for a given rifle, refer to a chart, like the one in Figure 2. Then find the make and model of the rifle and obtain the catalog or model number of the scope base; this is the one you need for your particular rifle. You will also need scope rings to match both the scope and base mounts.

For best accuracy, a telescope sight must be mounted solidly to the rifle so that it stays secure, shot after shot. It does not make sense to spend a lot of money for a scope and then secure it with a cheap mount. Precision-machined mounts that are designed for a particular scope and rifle cost more than some of the imported varieties, but the extra cost will payoff handsomely in dependability and increased accuracy.

A one-piece mount, such as the Redfield JR system, is the most dependable scope mounting system available. Of course, this type of

TACTICAL RAIL MODELS » *If you do not see your firearm listed here, please use our Scope Mount Selector on the side bar.*

MANUFACTURER & MODEL	1 PIECE RAIL WITH ZERO MOA		1 PIECE RAIL WITH 20 MOA		2 PIECE RAIL WITH ZERO MOA
Browning A-Bolt, 22 Micro-Medalion, WSM	--	M660	--	M660-20MOA	M618/618
Browning AB 3	M663	M664	M663-20MOA	M664-20MOA	--
FNH SPR with 8-40 screws	M649	--	--	--	--
H&R (Pre 1973) 300, 301, 330 & 370	M681	M681	--	--	--
Howa 1500 & 1700	M650	M651	M650-20MOA	M651-20MOA	--
Marlin 336, 375 &1895	--	--	M636-20MOA M636S-20MOA‡	M636-20MOA M636S-20MOA‡	--
Marlin XL-7	--	M676	--	M676-20MOA	--
Nosler M48	M682	M683	M682-20MOA	M683-20MOA	--
Remington 700	M673	M674	M673-20MOA	M674-20MOA	--
Remington Police with 8-40 screws	M671	M672	M671-20MOA	M672-20MOA	--
Ruger American Centerfire	M684	M685	M684-20MOA	M685-20MOA	
Ruger Mini 14 Ranch Rifle, 30, 77/22, 77/44, PC9 & PC40	A971	A971	--	--	--
Sako TRG 22 & 42	M678	M678	M678-20MOA	M678-20MOA	--
Savage Pre 2003 Bolt Action, Flat Receiver, Non Accu-Trigger	M668	M669	M668-20MOA	M669-20MOA	--
Savage Accu-Trigger, Round Receiver, All Center Fire§	M666	M667	M666-20MOA	M667-20MOA	--
Savage 10, 110 BA, FCP (Savage Round Receiver with 8-40 Screws)	--	--	M666-20-8	M667-20-8	--
Savage 220F Slug Gun	--	M667	--	M667-20MOA	--
Steyr SBS, Pro Hunter	--	--	--	--	M618/618
Tikka T3	M6T3	M6T3	M6T3-20MOA	M6T3-20MOA	--
Weatherby Mark V Standard 6 Lug & .240WM	M653	M653	M653-20MOA	M653-20MOA	--
Weatherby Mark V Magnum 9 Lug, Except .240 WM	M654	M654	M654-20MOA	M654-20MOA	--
Weatherby Vanguard	M650	M651	M650-20MOA	M651-20MOA	--
Winchester Model 70 Standard Pre & Post 64 with .860 RHS*	M675	M676	M675-20MOA	M676-20MOA	--
Winchester Model 70 WSM	M677	--	M677-20MOA	--	--

*RHS=Rear Hole Spacing: The measurement between the two rear screw holes, center to center.
‡The "S" in this part number denotes a silver Cerakote finish instead of matte black.
§ Will not fit the Savage Model 25.

Figure 2: Sight-base charts are necessary to match the mounts to the rifle.

mount cannot be adapted to all rifles, but it is the recommended mount when it can be used. The rotary dovetail feature acts as a cam to hold the ring into a mating dovetail in the base for a good, solid fit. This type of mount also allows you to remove the scope (but not the base), and replace it without losing the zero.

The split rings that hold the scope to the mount should be precision-bored to the exact diameter of the telescope sight, which is usually a 1 in. diameter. If the rings are precision-bored so that a full radius contact with the scope is maintained, an even pressure will be provided around the tube, thereby eliminating the problem of squeezing the tube out of round, which sometimes happens with strap-type mounting rings.

The Redfield JR base features an outside windage adjustment that overcomes scope mounting problems caused by drilling the mounting holes out of alignment with the bore, or where barrels have been threaded into the action at an angle.

Once the scope and mount have been obtained, remove the tap screws that prevent dirt and other foreign material from entering the screw holes. In most cases, there will be four. Position the mount or mounts in place, use the screws that accompany the mount, and loosely secure these screws to hold the mount or bases in place. Now, operate the action of the rifle to see if it functions smoothly. Often, in the case of bolt-action rifles, the factory-supplied screws are too deep and will jam the bolt, preventing it from

sliding smoothly. In this case, the screws will have to be shortened, either by cutting or grinding. Be sure to try the action again to make sure it works smoothly.

Remove the screws and mount bases from the receiver, and then clean the screw holes and screws thoroughly with a degreaser, such as the solution that comes with instant bluing kits.

At this point, fasten the mounting screws as firmly as possible in the screw holes to prevent them from coming loose during firing with a heavy-recoil rifle. Loctite is a commercial product that is recommended for such applications, and several types are available. Lock N' Seal, for example, can be applied to the screw threads to obtain a tight fit. The solution flows into and fills up to 0.015 in. gaps, then hardens into a tough solid with 1,700 psi (pounds per square inch) strength. Apply this solution to the threads of the screw, before tightening them. Wipe off any excess solution before it hardens. This should keep most of scope mount screws tight at all times.

For worn or extra-loose screws and rifles with an extra-heavy recoil, you might want to try Loctite Stud N'Bearing Mount solution. This sets up to 3,400 psi and usually requires heavy tools to remove the screw once it has set.

If you do not have any of the Loctite compound available, good results can be obtained with fingernail polish. Again, clean the threads, apply a small amount of fingernail polish to each thread, and tighten as before. It will harden quickly and lock screws in place.

With Weaver mounts, once the base is in position, the scope rings are installed on the scope, but the screws are not tightened down completely. The rifle should be secured in a padded bench vise during this operation. You want them snug, but not so tight that you cannot turn the scope. Secure the rings with the scope to the base mount, and then move the scope backwards and forwards, and rotate it until it is perfectly aligned and with the correct amount of eye relief. When aligned perfectly, carefully tighten the scope ring screws (one turn or less on each screw until all are snug) to hold the scope firmly in the desired position. If you tighten one screw more than another, the scope will be pulled out of line. Therefore, the main objective is to tighten all the screws evenly. The scope should now be mounted correctly.

Use B-Square's crosshair square, shown in Figure 3, to align the crosshairs vertically and horizontally. It accurately sets the scope's vertical *reticle*, or line, in position and can also be

Figure 3: B-Square crosshair square lets you square up a scope or front sight in seconds.

Figure 4: A shooting vise is a solid vise to hold rifles and shotguns for scope mounting, cleaning, etc. Padded rests and clamp jaws protect the gun's finish.

used to align front sight ramps in a vertical position. It is not necessary to remove the action and barrel from the gunstock when using the scope since it fits into the receivers of most bolt-action centerfire rifles. Furthermore, it is made of optical clear plastic that will not harm the finish of the gun. The B-Square crosshair square also squares the vertical index line with the bore.

BORESIGHTING

Some shooters mount their scope, take the rifle to the range, and attempt to sight it in. If a large enough target is available, this will sometimes work, but usually at the cost of many rounds of ammunition. A better way is first to boresight the rifle so the scope will be approximately lined up prior to shooting with live ammunition; the first one or two shots should be at a 12 in. x 12 in. target.

The optical boresighter provides a fast, accurate way to sight-in a rifle. It will give a lifetime of performance for a modest cost that is easily recovered in savings of ammunition alone.

If you are sighting-in a bolt-action rifle, you might want to do the boresighting the old way. Place the rifle on a steady rest, such as sandbags or a shooting vise (Figure 4), remove the bolt from the receiver and, looking down the bore from the receiver end, move the rifle around until the target, which should be placed at least 25 yd. away, is centered in the bore. Without moving the rifle, glance through the scope, making reticle adjustments with the knobs on the scope until the reticle is centered on the target. Look through the bore again to make certain that the rifle has not moved off target; if so, adjust it accordingly, as in Figure 5. If you are firing at a target beyond 25 yd., move the scope adjustments so the crosshairs appear about 1 in. below the center of the target. This will allow for bullet drop at the longer distance. Adjust the scope so the bore will be above the center of the target when the crosshairs are placed dead center.

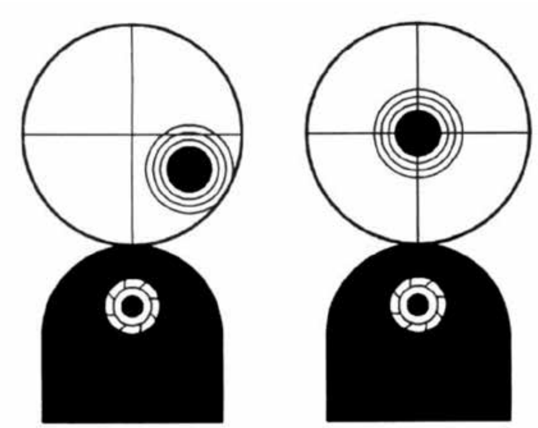

Figure 5: When boresighting a rifle, first sight through the bore rifle and line up your target. The target will appear as in the left-hand drawing. Then, adjust the scope until the target is centered in the crosshairs as shown in the right-hand drawing.

Figure 6: Collimator.

COLLIMATOR

If you use the optical boresighter, clamp the boresighter, or collimator (Figure 6), to a stud that is the correct size for the bore of the rifle being sighted-in; this stud will align with the axis of the bore (Figure 6a). The collimator is a simple optical device having an objective lens with a target grid. To the scope looking into it, the target is in focus, as in Figure 7. In use, this sighting grid is viewed in relation to the cross-hairs of the scope, the windage and elevation adjustment of the scope mounts, and/or the internal fine adjustments that bring the sights into alignment with the bore of the firearm.

Once the boresighter is in place, remove the adjustment turret caps on the scope. The elevation knob is marked UP on most scopes, with an arrow indicating the direction, which will move the point of impact up on the target. The windage knob is marked R (right), with a similar arrow marking.

The increments marked on the graduated scale around the knobs indicate the amount of point-of-impact movement in minutes of angle (MOA). One MOA equals $1/60°$ of arc. Since point-of-impact change is measured in angles, the amount of actual movement on the target increases as the distance to the target increases. For convenience, one MOA is set to equal 1 in. at 100 yd., although it is really 1.047 in. .

Using the scope adjustments described, align the scope reticle intersection with the center of the grid. The scope is now parallel to the axis of the bore. This adjustment will enable the first shot to be placed well within the edges of a normal-size target (for example, a 12 in. -18 in. square). You are now ready to sight-in the rifle.

SIGHTING-IN

When sighting-in a rifle, it is best to fire on a target within your expected average range. However, limited range facilities may prevent you from sighting-in the rifle at the desired

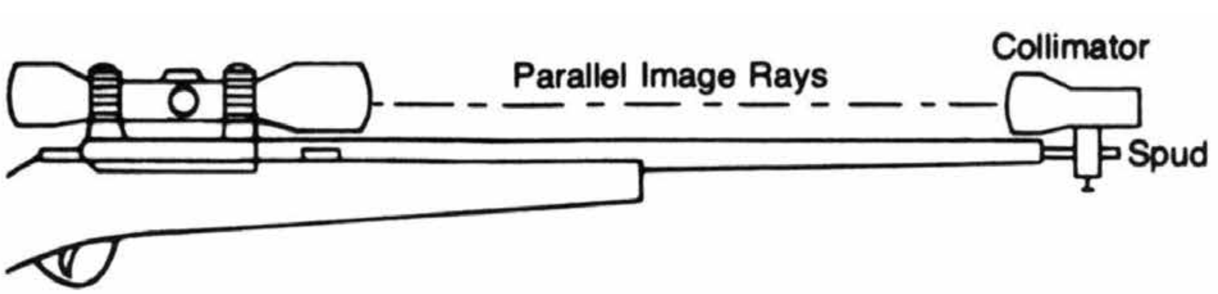

Figure 6a: Collimator in position for presighting a telescope sight.

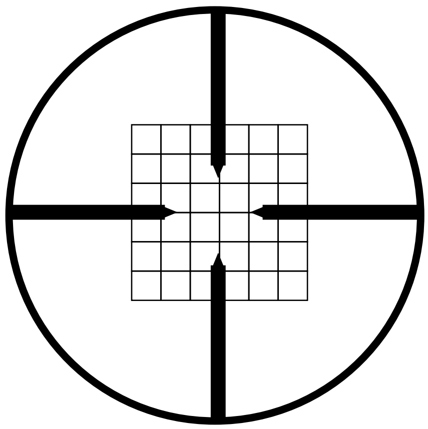

Figure 7: When sighting-in with a bore scope, this is the image that can be seen when the collimator is in place.

distance. If you obtain some of the readily available ballistics charts, this handicap can be overcome easily, allowing you to sight-in your rifle at a lesser range, yet having the point of impact be almost exactly as you want it for longer ranges.

For example, let's assume that you have a .270 Weatherby Magnum rifle and you are using 130-grain factory bullets. Let's further assume that you want the rifle sighted-in at 200 yd., but your practice rifle range is only 100 yd. By referring to the Weatherby ballistics chart, you find that the midrange trajectory of the 130-grain bullet at 200 yd. is 1.8 in. . Since midrange of 200 yd. is 100 yd., if you sight the rifle in to shoot 1.8 in. high at 100 yd., you should be zeroed-in exactly at 200 yd., or at least very close.

Take this example a bit further. Let's say we want the bullet to strike the target at 300 yd. Again referring to the Weatherby chart ("Path of Bullet Above or Below Line of Sight"), we find that the 130-grain bullet, when zeroed-in at 300 yd., will strike 2.8 in. high at 100 yd., so that it will be "dead on" at 300 yd.

When firing, scope adjustment knobs are moved until the rifle places the bullet where it is desired.

Sighting-in should be done from a steady rest, such as a solid benchrest, tripod, or sandbags. You should also sight-in your own rifle since no two people hold or fire a rifle in exactly the same way.

To zero-in the rifle, fire three shots from the desired range, using the center of the three-shot group as the hypothetical point of impact. Make the proper scope adjustments until the group is landing where you want it.

The rifle should be zeroed-in just prior to using it for target shooting or hunting.

Humidity and other changes in the weather will change the bullet impact on the target. So, from time to time recheck your rifle to see if it is holding its original point of impact. If not, adjust it accordingly.

TOP-EJECTING RIFLES

Some rifles, like the older Winchester Model 94s, eject the fired cartridge through the top of the action, making it necessary to mount the scope in an offset position in order to allow the cartridge to pass. One solution to this problem is to use a mount designed for top-ejecting rifles. Newer top-ejecting rifles require no drilling and tapping, and the mounts are installed similar to other types on which the receiver has been drilled and tapped at the factory. However, when using these scopes the shooter has to tilt his or her head slightly in order to view through the scope since it is offset from the line of the bore, as shown in Figure 8.

The offset scope mounts do have the advantage of being able to use either the scope or the open iron sights. This can be to the shooter's advantage if the scope should become fogged or if there is not enough light to adequately use the scope.

The advantage of using either the scope or iron sights has further benefits on close shots in wooded areas. In fact, many hunters use see-through mounts on rifles that will handle conventional scope mounts adequately. These see-through mounts are designed with two sets of rings, with the scope mounted in the upper set.

Figure 8: To use a scope sight on some rifles, the scope must be offset to allow room for the cartridge to eject out of the top of the receiver. Side view and top view shown.

If the iron sights are to be used, the shooter aims through the lower set of rings, using the existing iron sights on the rifle. If the scope is to be used, the shooter aims through the scope.

Using offset or see-through scope mounts on rifles other than bolt-action rifles has been a problem for gunsmiths. Lever-action, slide-action, and semi-automatic rifles do not allow access to a clear view of the bore without a prism boresighter. Neither could a collimator be viewed accurately with such sights until the offset spud was introduced (Figure 9).

Figure 9: B-Square offset spud for aligning offset and similar types of scope mounts.

This collimator offset spud can be used with any boresighter to allow boresighting with any offset, side, see-through, or high-mounted scopes that are out of range of the conventional boresighter. The *offset spud* fastens to any boresighter spud, and any boresighter, or collimator, can be fastened to it.

DRILLING AND TAPPING FOR SCOPE MOUNTS

Most of the older rimfire and centerfire rifles, especially those designed for military use, were not supplied with drilled and tapped holes (or grooves) for mounting scope sights. Some of the older sporting rifles are well adapted to telescopic sights; but many of the military rifles and some sporting rifles require major alterations to enable a scope sight to be used satisfactorily.

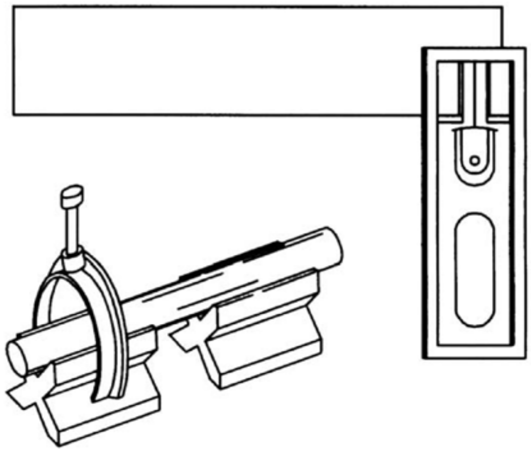

Figure 10: V-blocks and two tri-squares are essential for locating holes in receivers to be drilled. Sight jigs are better and quicker, but also more expensive.

Mausers and Springfields, for example, require altering the bolts so they will miss, or pass by, the scope. The ears of the receiver sight on Enfield rifles must be milled or ground off to accommodate the scope mount. Other rifles may require that the scope be side-mounted, or offset, to allow functioning of the action and to eject the fired cartridge properly. Each problem will be dealt with separately.

Scope drilling jigs are used almost exclusively for drilling and tapping scope mounts. Many professionals make their own, although various types are available from gunsmith supply houses. By using these jigs, screw holes can be located and drilled in a fraction of the time it once took, so there is little reason for professional shops to use any other method. However, from time to time a professional shop may get in a rifle for which no jig is readily available, but it would not pay to make a jig for just one rifle.

The hobbyist might want to try mounting a scope, but does not want to go the expense of purchasing one of the scope jigs, which usually start out at around $100. It would be better to take it to a professional shop and have the job done for under $20. Still, there may be some who want to do the work themselves. For those who do, the following describes the procedure of mounting a scope from scratch.

You will need a few tools and know how to use them before you should even begin to think about drilling and tapping a scope mount. These include an accurate level, V-blocks, and tri-squares (Figure 10).

Obtain a scope base that is suited to the rifle you want to put it on. Manufacturers have bases for most rifles. If a factory base is not available, existing bases will have to be modified, or a new base will have to be made from scratch to fit the rifle exactly.

Clamp the sight base to the rifle in the exact mounting position. Use machinist's clamps for this operation. Be careful to ensure that this base is level, straight, and true before locating and spotting the correct position for the screw holes, which will have to be drilled and tapped.

To locate these holes accurately, some reference point must be found on the rifle to check the work as it progresses. The rifle must also be resting on a perfectly level surface, such as a piece of plate glass, or a smooth, level table or board.

Place the barrel and receiver on this level surface, resting the barrel in V-blocks, and then proceed to get the barrel and receiver absolutely vertical on this level surface. This is usually accomplished by taking some square surface on the receiver, and holding it parallel or at right-angles to the surface plate by means of small steel tri-squares. This square surface on the receiver will vary with the make of rifle, but on a typical Mauser receiver, this flat surface is located on the underside of the receiver.

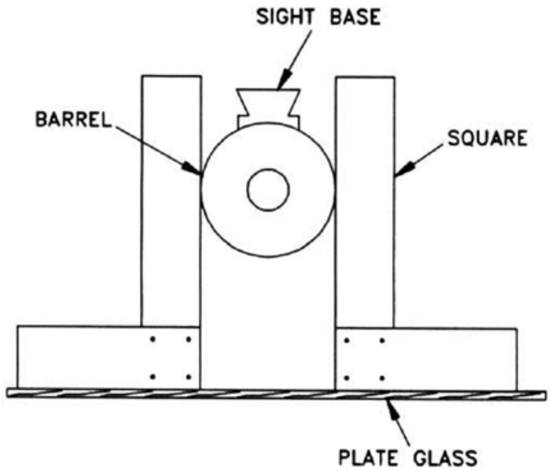

Figure 11: One way to align scope bases on a rifle barrel.

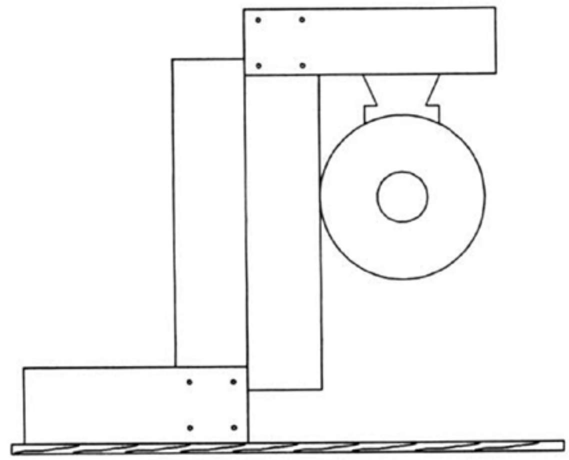

Figure 12: Check the sight base again by changing the position of the squares, this time trying the top of the base to make sure it is level and parallel to the surface plate.

On most single-shot receivers the sides of the receiver are used and the squares are placed upright on the surface plate with the vertical arm brought up so the receiver can be trued against it. With some rifles and shotguns, it is best to try to align on two square surfaces, and if there is any difference divide it equally.

Once the barrel and receiver are exactly vertical with respect to the surface plate, they must carefully be kept in this position until the sight base is securely clamped in its correct position.

Now, carefully clamp the sight base in its approximate position on the rifle receiver, using a few machinist's clamps for holding. One way to accomplish this is to place a square up against either side of the barrel. With inside calipers, carefully measure from the square to the side of the base on each side to make sure that the base is in the absolute center of the barrel (Figure 11). This should be done at both the front and rear end of the base. Then change the position of the squares to ascertain that the top surface of the base is absolutely level and parallel to the surface plate, as shown in Figure 12.

With the sight base absolutely correct, the clamps are then tightened so there is no danger of the base moving out of alignment. To ensure that this will not happen, it is a good idea to scribe a narrow line around the sides of the base so that any movement will be readily recognizable.

There are usually three or four screw holes in the base to hold the base to the receiver. Therefore, a spot must be located exactly in the center of these screw holes to mark the drilling point.

To obtain the exact center by the method described, it is best to use the sight base itself as a guide. Use a drill that is the same size as the screw hole in the sight base. This is not the same as the size used for the hole that will be tapped. Since the sight base is clamped firmly to the receiver, the barrel and receiver may now be removed from the V-blocks, and the assembly clamped in a drill press vise under the drill press, or you can leave the barrel and action where they are, and use a breast drill for the drilling.

Start the drill down straight through the hole; using the hole in the base mounts as a guide,

Figure 13: Three types of taps in common use: top to bottom, the bottoming tap, the plug, and the taper.

drill a spot in the receiver that is at the exact center and correct for the receiver screw hole. At the same time, make sure the drill does not move the base(s) out of line. Mark all the holes in this manner for a two-piece mount; or just mark one front hole and one rear hole for a one-piece mount. Now you can remove the clamps and sight base for the rest of the drilling.

The most common size of a sight-base screw is a 6-48, requiring a No. 31 wire-gauge drill to drill the pilot hole prior to tapping. While a drill press is best to ensure proper straightness of the hole, a hand or breast drill will do for those who are careful. However, before drilling, examine the areas carefully to be drilled to determine the depth of each hole. Obviously, you must not let the drill enter the bore. This mistake has been made by both professionals and amateurs, so be extremely cautious in the barrel area.

Most drilling will take place in the receiver area, and although not as critical as the barrel area, be careful not to drill too deeply or through areas that conflict with the functioning of the action. Go slowly and use a depth gauge to show how deep you are at any given time. You must drill deep enough to get a good bite on the screw, which is usually about three threads, or about ⅛ in. If there is enough room, 3/16 in. is better.

Figure 13 shows the three types of common taps: the taper, the plug, and the bottoming tap. For screw holes drilled completely through the receiver top, a conventional No. 2 taper tap will suffice for the entire tapping operation. For holes that go only partially through, a bottoming tap should be used, after starting the thread with the taper tap, to ensure cutting the threads squarely to the bottom of the hole. When all holes are correctly tapped, dip the screws in oil and screw the sight base onto the receiver.

Caution. When using the bottoming tap, it is quite easy to snap the tap off once it reaches bottom if too much force is applied. It is very difficult to get the broken tap out, so be extremely careful. When tightening the screws, use the proper screwdriver to avoid marring the screw heads.

With the base(s), in place, attach the scope rings and scope and inspect all items for correct alignment. If everything seems in order, remove the screws and bases, clean off all surplus oil, and apply Loctite solution to freeze the screws in place.

Figure 14: When mounting two-piece bases, they must be in absolute alignment with each other on top of the receiver.

When mounting two-piece bases, they must be perfectly aligned with each other on top of the receiver, as shown in Figure 14. To obtain this result, many gunsmiths use a steel rule that is true and accurate. The rule is applied to the sides of the bases. Make sure it touches both bases equally for their entire length, showing them to be in line. Make any necessary adjustments to align them. Both bases should be fitted at the same time while the barrel and action are on the V-block on the surface plate. Spot the holes simultaneously.

Boresight and zero the rifle the same way as you would for mounting factory-tapped rifles.

DRILLING HARDENED RECEIVERS

Many older military receivers have been case-hardened. With such receivers, you can dull several drill bits and not even begin to scratch the surface. Sometimes, you can take a rotary tool and grind the surface of the receiver exactly at the spots you intend to drill so the bit will penetrate the softer inner metal; but sometimes even this will not work. When a situation like this arises, the only solution is to spot-anneal the areas to be drilled, as in the rifle in Figure 15. This is accomplished by heating the area and then letting it cool slowly. Be careful to soften only the spot where the screw holes will be drilled and not the entire receiver, otherwise the receiver might be weakened so that it will not withstand the strain of the breech pressure when fired.

To spot-anneal a receiver, first locate the screw holes and then clamp the sight base in place. Now, mark the location of each hole to be drilled. Remove the sight and use a rotary tool to polish the spots with an emery wheel to remove the finish and leave the spots bright and smooth. There will be small bright marks on the receiver at each location of the screw holes where they are to be drilled. The tip of a soldering iron can then be held to each of these polished spots until the bare metal turns a dark blue. Then let the metal cool slowly. This will usually anneal, or soften, the receiver surface so the drill bit will enter without difficulty and not weaken the surrounding metal.

Some gunsmiths prefer to use a torch rather than a soldering iron because the heating is quicker. This will work, but extra precautions must be taken prior to heating. Drill holes through a

Figure 15: To drill and tap this case-hardened Springfield 1903 receiver for a one piece scope mount, the spots on the receiver require annealing where the holes where drilled.

piece of tack cloth and then secure the sheet of tack cloth around the receiver, aligning the holes in the tack cloth with the polishing marks on the receiver. Now, wrap wet cloths all over the receiver and around the edges of the asbestos sheet so that the entire receiver is wrapped with the exception of the area to be spot-annealed. To anneal, use a torch whose flame blows into the holes of the tack cloth so that the steel underneath becomes hot. Again, continue heating until the polished metal surfaces become a dark blue color, then allow the receiver to cool slowly.

Once annealed, the holes are relocated, marked, spotted, drilled, and tapped. Just make sure that you allow sufficient time for the metal to cool slowly before starting the drilling and tapping operation.

You can skip this annealing operation by using a solid carbide drill. Brownells offers two sizes, a number 31 for 6-48 taps and a number 28 for 8-40 taps. They will drill through the hardest receivers, or can be used to "crack the skin" of case-hardened receivers after which a regular drill bit is used to finish the job.

However, there are two problems with the carbide drills. First, the solid carbide drills are easily broken. If kept clean they are less likely to bind and break.

Second, if the inner steel is extremely hard, the taps are likely to break and getting them out can be quite difficult. But carbide drills are recommended to those who are capable of using good judgment and proper care. These drills should not be used on softer steels and should be used only after other drills have failed, or when the hardness of the steel is known.

SIGHT MOUNTING JIGS

As mentioned previously, most professional gunsmiths use drill jigs to spot drill holes in receivers for mounting sights. The relatively high cost of these jigs is more than offset with only three or four drilling and tapping jobs.

B-Square Receiver Sight Jig. This non-marring, aluminum jig clamps to receiver bolt-lug grooves in bolt-action rifles for accurate positioning of the hardened steel drill guide bushing. It eliminates the need for the time-consuming method of spotting holes, and is used for receiver sights and to align holes on a bore's centerline axis. The jig spaces holes to match the sight exactly. Use it on Springfields, Enfields, and Mausers.

B-Square Professional Drill Jig. This is the fastest device known for aligning, drilling, and tapping scope mount holes in the receivers of Springfields, Enfields, Mausers, Remington Model 30s, and similar bolt-action rifles.

To use, remove the bolt of the rifle and insert the drill jig. It automatically locates the holes in reference to the recoil shoulder and aligns and spaces the holes vertically on the centerline of the receiver. Holes are all drilled at one time.

Figure 16: Sight mounting jig.

The hole spacing matches the mounts made by Weaver and Redfield.

Both of these jigs are recommended for professional gunsmiths if much scope work is encountered. The work involved is at least 10 times faster than setting up with squares and V-blocks as discussed previously.

The Forster Jig. For gunsmiths doing much sight work on firearms other than the bolt-action rifles described above, the Forster universal sight mounting fixture, shown in Figure 17, is almost impossible to do without. It will handle all bolt-action, lever-action, slide-action, and semi-automatic rifles as long as the barrel can be laid in the V-blocks of the fixture.

The Forster fixture will locate the holes to a standard predetermined spacing built into the overarm, or to any spacing by sliding the overarm in either direction. "Walking" or "run out" of the drill is eliminated since the drill is guided through a hardened and ground drill bushing. Tapping is done through another bushing of the correct tap size, and eliminates cocking the tap— a major cause of tap breakage and sloppy screw holes. The sliding overarm has three holes with standard spacing of 0.500 in. and 0.860 in. between centers into which the interchangeable drill and tap guide bushings fit. The overarm is keyed and slides in a T-slot, keeping it in true alignment with the center of the gun barrel.

The main body of the fixture is cast aluminum. The two V-blocks are adjustable for height and are made of hardened steel accurately ground on the V as well as on the shaft. A fixture like this belongs in every professional shop.

To use, first remove the stock from the gun to be drilled and tapped. In most cases, only the forend needs to be removed on rifles with two-piece stocks, such as the Marlin 336 and Savage Model 99. The Remington 760 requires the removal of the slide and slide bolt, as well

Figure 17: The Forster universal sight mounting fixture is invaluable for shops doing extensive scope mounting.

Figure 18:Forster Jig V-Blocks.

as the bolt mechanism. The trigger mechanism can usually be left in on most bolt-action rifles. Tubular magazine rifles must have the magazine removed before placing the barrel in the fixture for drilling. The barrel is then laid in the V-blocks, and the action is laid over the end of the fixture with the clearance slot. Whenever possible, the barrel to be drilled should be positioned so that the action is close to the rear V-block, with the cylindrical or straight portion of the barrel supported by the V-block.

Slide the overarm in place over the portion of the action to be drilled and raise the rear V-block up to bring the action or receiver in contact with the correct size drill bushing. Next, measure the diameter of the barrel with a micrometer at the points of contact at the front and rear of the V-blocks. Since most barrels are tapered, it will be necessary to raise the front V-block. The amount is determined by subtracting the smaller diameter from the larger diameter, and then multiplying this value by 0.707. The resulting answer will be the height the front V-block must be raised above the rear V-block. This measuring can be done with a steel machinist's rule. If extreme accuracy is desired, use a feeler gauge between the top of the machined boss and the bottom of the V-block. Many gunsmiths use outside calipers for this operation.

Once the V-blocks are adjusted to their proper height, clamp the barrel lightly in the V-blocks using the aluminum pads under the clamp screws to avoid marring the barrel. On bolt-actions rifles, raise the flat top support pad into firm contact with the flat bottom of the action. This squares up the action and acts as a support during the drilling operation. The clamp on top of the leveling overarm may be moved over any part of the action. Now tighten the clamps.

Some receivers will not have flat bottoms, but they still can be lined up by means of a square from the top of the overarm, or any other machined surface on the fixture. The rifle action can also be lined up by using a level; however, be sure the fixture itself is level before lining up the rifle.

One method used by many gunsmiths to locate mounts is to place the mount on the action or barrel in the desired position and mark the forward hole on the gun with a scriber or pencil. With the locator pin pointing down in the front hole of the overarm, slide it over the gun so the point lines up with the mark and lock it in place. Drill and tap this hole. Now, screw the mount onto the gun with one screw. Loosen the overarm and, with the tapered point of the locator pin, place the overarm over the second hole in the mount and lock it in place. Lock the spacer block against the overarm. The overarm then can be moved out of the way, the mount removed, and the overarm reset against the spacer block. The second hole is then drilled and tapped. Other holes in the mount can be

located and drilled in the same way. Do not drill the holes with the mount in place; this may prevent you from drilling the holes on the true center of the action.

When drilling for receiver sights, line up the barrel in the V-blocks in the usual way, but turn the action sideways and square it up using a small square laid on top of the overarm. Locate the first hole and proceed as already described. The same procedure is followed when mounting side mounts, but holds true only if all the holes are in line with the center of the rifle bore.

If the desired holes are not on the centerline of the barrel, the fixture can still be used to hold the gun squarely and steadily in the drill press. In this case, the over-arm is not used.

When drilling and tapping for a front sight on a barrel, the position of the gun is reversed; that is, the muzzle end is placed at the notched end of the fixture. The V-blocks, in this case, are raised high enough so the drill bushings will contact the barrel. Allowance must be made for the taper in the barrel. It will be necessary to square up the gun with a level. Shotgun beads are mounted by following the same procedure.

When first using this fixture, go slowly and carefully, double-checking all measurements and your setup to make sure you are drilling the holes exactly where you want them. Also make sure that the V-blocks line up squarely by tightening the screws gently at first, so that the flat of the screw contacts the flat of the shaft squarely. A twisted V-block will throw you off due to the taper in the barrel, and especially so if the barrel is supported at a point where the taper is abrupt.

Extreme care must be exercised to prevent metal chips from getting between the finished surfaces of the overarm and the body of the fixture when the overarm is moved. This is equally true of the spacer block. If chips are allowed to lodge between the two finished surfaces, they will impair the inherent accuracy of the fixture. Brush away all chips with a small, dry brush before loosening the overarm and spacer block. A blast of compressed air will also do the job quickly. Do not use force when tightening the screws holding the over-arm and spacer block.

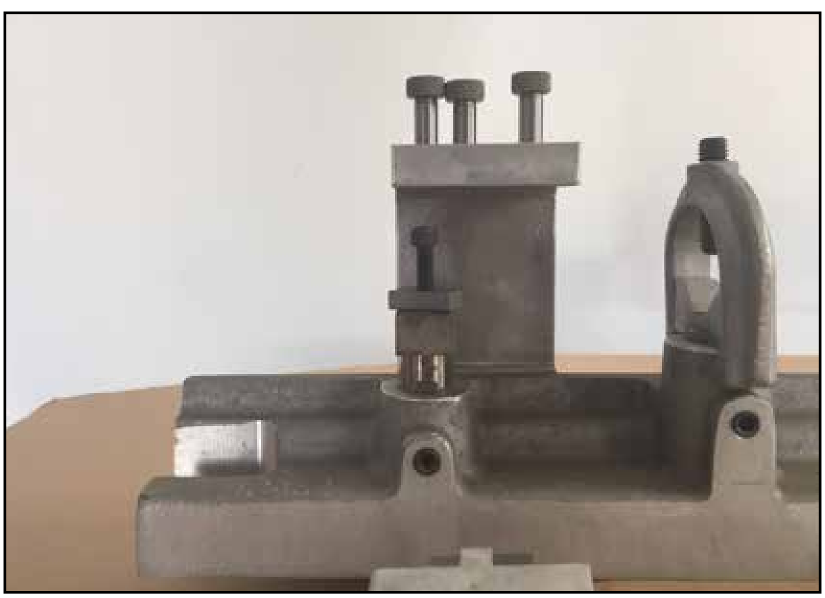

Figure 18:Forster jig tightening feature.

NOTES

Chapter 5 - Scope Mounting

Introduction

Installing telescopic sights on a rifle can be a profitable undertaking. All you need is a scope, rings to attach the scope to the firearm, and a mounting base. The mounting base is a machined surface that is either part of the firearm, or a removable plate that is securely fastened to the firearm. Scopes can be installed on rifles, shotguns, and handguns.

Most centerfire bolt-action rifles manufactured during the past couple of decades are factory-drilled and tapped to accept telescopic scope mounts. Other rifles have a grooved receiver or an integral scope base. Also, many high-power handguns have a provision for scope mounting.

Rifles that have been drilled and tapped at the factory for scope sights are easy to work with. You should experience little difficulty in doing a good job provided the project is done in recommended sequences.

The installation of scope sights on rifles that have no factory provisions can be quite a task for amateurs and professionals. Poor technique in this phase of gunsmithing is common. In most cases, shoddy sight work is usually attributed to aligning the sight mounts in their correct positions by the eye alone. Marking the location for screw holes by crude and inaccurate methods is another factor. There is a right and wrong way of installing sights, and this kit will give you the proper methods and principles that will always result in correct sight installation.

Mounting Scope Sights

There are two classifications of scope rings: Weaver and Redfield. Weaver rings, shown in Figure 1, are designed to fit over the mount. They fasten to the mount by a clamp on the ring. Redfield rings, shown in Figure 2, are designed to fit into a hole in the front mount. The rear ring fastens to the base by way of a windage screw on the base itself.

GROOVED RECEIVERS

Most .22 rimfire rifles including the .22 Winchester Magnum have grooved receivers, as shown in Figure 3. This groove on the receiver is the actual scope mount and accommodates Weaver-style scope rings designed especially for these rifles.

Many of the scopes designed for .22 rimfire rifles are furnished with rings at no extra cost. Other scopes require rings to go with the scope. The majority of these rings will be either ⅞ in. or 1 in. in diameter. These rings are designed especially for grooved receivers on .22 rifles.

The rings are installed on the scope before it is installed on the rifle. Remove the screws that fasten the top half of the ring to the bottom half, and remove the top of the ring. Place the scope in the bottom of the ring and replace the top of the ring. Install the screws, but do not tighten them completely at this time. The screws should be tight enough to hold the scope in position, but you should be able to rotate the scope in the ring with moderate finger pressure.

The installation of a scope requires aligning the mounting clips in the receiver groove, and sliding the scope and rings into position. Before final tightening, however, snug the screw clamps up so that the scope and mounts will slide in the groove. Then, test the scope for correct eye relief, or distance between the eye and the scope. Tighten the retaining screws by hand, and turn the final one-quarter twist with a screwdriver.

There is no correct measurement for eye relief. The correct eye relief allows the shooter to see through the scope without any shadow when the head is in normal shooting position. This varies, since people hold their heads in different positions when they shoot. When installing a scope

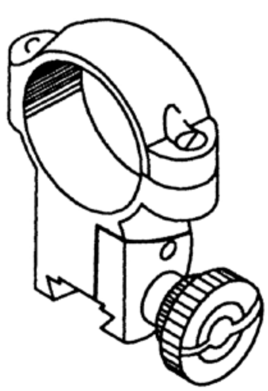

Figure 1: Weaver-style rings are designed to fit over a dovetail base.

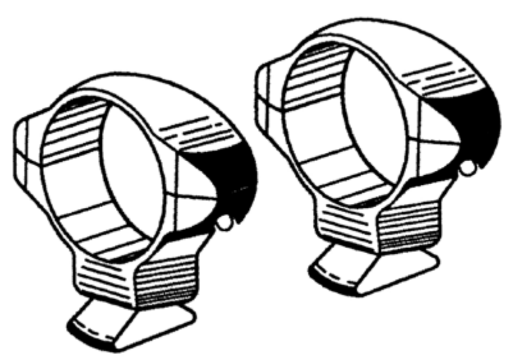

Figure 2: Redfield-style rings are designed to fit into a slotted base.

Figure 3: The receiver on the Marlin .22 rifle is grooved for scope rings.

for a customer, you may have to readjust the eye relief after you have zeroed the scope.

INTEGRAL SCOPE MOUNTS

Some rifles and handguns have integral scope mounts. These mounts are machined into the receiver (Figure 4). Firearms with these mounts usually have Weaver-type rings included.

Mounting scopes on this type of firearm is as easy as mounting a scope on a grooved receiver. First, place the rings on the mounts and tighten the mounting clamps securely. Remove the top half of the rings and place the scope in the rings. Replace the top half of the rings and loosely install the ring screws. Slide the scope in the rings to set the eye relief, and tighten the ring screws slightly. You should still be able to rotate the scope in the rings.

DRILLED AND TAPPED RECEIVERS

While scope mounts for .22 rimfire rifles normally use universal clamps that fit into the factory-grooved receivers, centerfire rifles are different. With centerfire rifles that are drilled and tapped for bases, a base or mount that exactly fits the particular rifle must be obtained.

Depending on the rifle, the scope mounts may be either a one- or two-piece base. To select the proper base for a given rifle, refer to a chart like the one in Figure 5, to find the model and make of the rifle. Find the catalog or model number

Figure 4: Integral scope mounts.

Figure 4A: Redfield JR system.

BROWNING

	Notes	Top Mount Bases					Steel Lock Mounts Complete System Matte	Side Mount Bases	Grand Slam Top Mount Bases				Grand Slam Dovetail Bases	
Model of Firearm		Standard			Extensions				Standard		Extensions		1-PC Base	2-PC Base
		Rear	Front	1-PC	Rear	Front			Rear	Front	Rear	Front		
1885 High Wall (Octagon Barrel)	1,3	11 (48011)	29 (48029)											
22 Auto	18			60A (48064)										
Sako Actions in 243, 308, 22-250, 222 & 222 Mag.		72 (48072)	71 (48071)											
A-Bolt, A-Bolt 22 Stalker; Medallion		47 (48047)	47 (48047)				49719						48922 L/A	48904
Black													48924 S/A	48904
Matte		47M (48503)	47M (48503)						S47 (48228)	S47 (48228)			48923 L/A	48905
Matte													48925 S/A	48905
Silver		47S (48003)	47S (48003)											
A-Bolt Shotgun (Matte)		47M (48503)	419M (48437)											
A-Bolt (European Model), Mod 52, 52C	5	85 (48085)	85 (48085)											
Bolt Action BBR, Hi-Power, Other Cal. (Older Mod.)		45 (48045)	46 (48046)			402 (48108)	49721	5 (48405)	S45 (48226)	S46 (48227)		S402 (48247)		
Silver		45S (48510)	46S (48004)			402S (48430)								
BAR, BAR II, Mark II, BLR Lightning (Lever), BPR	5	54 (48054)	54 (48054)				49720						48932	
Matte									S54 (48230)	S54 (48230)			48933	
BLR (Lever Action)		25 (48025)	25 (48025)						S25 (48223)	S25 (48223)				
BLR with Flat Top Receiver (Older Models)		28 (48028)	28 (48028)											
BBR (Bolt Action), Long & Short Actions		47 (48047)	46 (48046)			402 (48108)	49718							
Matte		47M (48503)	46M (48502)			402M (48429)			S47 (48228)	S46 (48227)		S402 (48247)		
Silver		47S (48003)	46S (48004)			402S (48430)								
A-Bolt WSSM		427 (48450)	47 (48047)											48911 (matte)
BAR (Matte)				432M (48456)										
T-Bolt	27	15 (48015)	15 (48015)											

Figure 5: A scope mount base chart.

Figure 6: (A) Strap-type scope ring, Weaver style, and (B) bored-type scope ring, also Weaver style.

of the scope base; this is the one you need for your particular rifle. You will also need scope rings to match both the scope and base mounts.

For the best accuracy, a telescopic sight must be mounted solidly to the rifle in such a way that it stays secure shot after shot. Precision-machined mounts that are designed for a particular scope and rifle cost more than some of the imported varieties, but the extra cost will pay off in dependability and increased accuracy. Also, remember that your reputation rides on every job. Be sure that you always use quality parts.

A one-piece mount, such as the Redfield JR system (Figure 4A), is the most dependable scope mounting system available. Of course, this type of mount cannot be adapted to all rifles, but it is the recommended mount when it can be used. The rotary dovetail feature cams the ring into a mating dovetail in the base for a solid fit. This type of mount also allows you to remove the scope, not the base, and replace it without losing the zero.

The split rings that hold the scope to the mount should be precision-bored to the exact diameter of the telescopic sight, usually 1 in. . If the rings are precision-bored so that a full radius contact with the scope is maintained, an even pressure is provided around the tube. This eliminates the problem of squeezing the tube out of round, which sometimes happens with strap-type mounting rings. Figure 6 shows a strap-type and a bored-type scope ring. Both rings are to be used with 1 in. scopes.

Once the scope and mount have been obtained, remove the tap screws that prevent dirt and other foreign material from entering the screw holes. In most cases, there will be four. Position the mount or mounts in place, use the screws that accompany the mount, and snug these screws down to hold the mount or bases firmly in place. Do not tighten firmly at this time. Now operate the action of the rifle to see if it functions smoothly. Often, in the case of bolt-action rifles, the factory-supplied screws protrude too deeply and will jam the bolt, preventing it from sliding smoothly. In this case, the screws will have to be shortened, either by cutting or grinding. Try the action again, and repeat this procedure until the action works smoothly.

Remove the screws and mount bases from the receiver. Then thoroughly clean the screw holes and screws with a degreaser. Apply Loctite to the mount screws and reinstall them in the bases. Tighten the mounting screws as firmly as possible to prevent them from shooting loose. This is especially important with a rifle with heavy recoil.

DRILLING AND TAPPING FOR SCOPE MOUNTS

Most of the older rimfire and centerfire rifles, especially those designed for military use, were not supplied with drilled and tapped holes or grooves for mounting scope sights. Some of the older sporting rifles adapt well to telescopic sights, but many of the military rifles and some sporting rifles require major alterations to enable a scope sight to be used satisfactorily. Your regular lessons cover these alterations.

Scope-drilling jigs, like the one shown in Figure 7, are used almost exclusively for drilling and tapping scope mounts. Many professionals make their own, although numerous types are available from gunsmith supply houses. By using these jigs, screw holes can be located and drilled in a fraction of the time it once took. There is little reason for professional shops to use any other method.

The jig shown in Figure 7 is supplied with the correct drill and tap. To use this jig, remove the bolt of the rifle and insert the drill jig. It automatically locates holes in reference to the recoil shoulder, and aligns and spaces holes vertically on the centerline of the receiver.

Place the #31 drill bit that is included with the drilling jig in a drill press. Place the receiver on the drill table so the jig is under the drill bit. Align one hole in the drilling jig with the drill bit. Be sure the jig is level, and clamp the barrel and receiver to the table of the press. Use padding to protect the finish of the firearm. Drill the first hole and repeat this procedure for the remaining holes. The hole spacing matches the mounts made by Weaver and Redfield.

Remove the receiver from the press and remove the drilling jig from the receiver. The next step is to tap the holes. The drilling jig includes a 6 x 48 tap which is used to cut the threads in the holes. Before using this tap, however, clean the holes so they are free of metal shavings.

Figure 7: A scope-drilling jig.

Mount the receiver in a padded vise. Place the tap in the hole and turn the tap clockwise one-quarter turn. Pour a small amount of oil in the grooves of the tap and proceed to cut the threads. With a wrench, turn the tap one turn clockwise, then a half turn counterclockwise. This will keep the teeth of the tap clean. Continue in this manner until the tap bottoms out in the hole.

Some of the receivers will allow you to drill a hole completely through them. If you do, be sure to dress the bottom of the hole with a file. This will prevent binding of the action.

Once the holes are drilled, tapped, and thoroughly cleaned, the scope mounts are installed as discussed previously.

Figure 8: This particular collimator kit includes 14 studs, which will fit bores from .17 to .45.

Zeroing the Scope

Some shooters mount their scopes, take their rifles to the range, and attempt to sight-in. If a large enough target is available this will sometimes work, but usually at the cost of many rounds of ammunition. A better way is to first boresight the rifle so the scope will be approximately aligned prior to shooting live ammunition. The optical boresighter provides a fast, accurate way to sight-in a rifle and saves ammunition.

Place the rifle on a steady rest, such as sandbags, a padded vise, or the gun cleaning fixture discussed in a previous kit. Position the rifle so that it is perfectly vertical in a heel-to-receiver orientation. Look through the scope and rotate it so the crosshairs are exactly horizontal and vertical.

Once the rifle and scope are in the correct positions, carefully tighten the scope ring screws (one turn or less on each screw until all are snug) to hold the scope firmly in the desired position. If you tighten one screw more than another, the scope could be pulled out of line by the screw pressure. Then, tighten each of the eight ring screws about a half turn in rotation until the desired tension has been obtained.

COLLIMATOR

The collimator is a simple optical device — an objective lens with a target grid at the end. Through the scope, the target grid is in focus. In use, this sighting grid is viewed in relationship to the crosshairs, or reticle, of the scope. Windage and elevation adjustment of the scope, or windage adjustment of the mount, brings the sights into alignment with the bore of the firearm. The collimator can be used with all scopes for rifles and handguns.

To use the collimator, clamp it to a stud. From the 14 studs shown in Figure 8, choose the stud that is the correct size for the bore of the rifle being sighted-in. Position the stud so the screw in the collimator contacts the flat part of the stud. Insert the stud in the muzzle of the gun and push the collimator into the bore so it is flush against the muzzle, as shown in Figure 9.

Figure 9: Push the collimator into the bore so it is flush against the muzzle.

Figure 10: See-through scope rings mount the scope higher than normal, like these Millett see-thru scope mounts.

Many shooters will prefer a scope ring that allows them to use either the factory sights for short shots or a scope for long shots. This see-through scope ring, shown in Figure 10, mounts the scope higher than normal. To use the collimator with this type of ring, you will need an adapter like the one shown in Figure 11. This will raise the collimator so it is in line with the scope.

Once the collimator is in place, remove the adjustment turret caps on the scope, as shown in Figure 12. The elevation knob is marked "UP" on most scopes, with an arrow indicating the direction to move the point of impact up on the target. The windage knob is marked "R" for right, with a similar marking.

The increments marked on the graduated scale around the knobs indicate the amount of point-of-impact movement in minutes of angle (MOA). One MOA equals $1/60$ of a degree of arc. Since point-of-impact change is measured in angles, the amount of actual movement on the target increases as the distance to the target increases. For convenience, one MOA equals 1 in. at 100 yd.

Using the scope adjustments described, align the scope reticle intersection with the center of the grid. The scope is now parallel to the axis of the bore. This adjustment will enable the first

Figure 11: Boresighting a rifle with see-through rings will require an adapter between the stud and the collimator.

shot to be placed well within the edges of a target 12-18 in. square. You are now ready to sight-in the rifle.

SIGHTING-IN

When sighting-in a rifle, it is best to use a target at the distance you normally expect to be shooting. However, the length of the range you have access to may prevent this. For example, your customer may want the rifle sighted-in at 200 yd. Your range is only 100 yd. This problem can be overcome by using ballistic tables like the one in Figure 14 on the next page.

For example, if you wanted to sight-in a .308 Winchester for 200 yd., and the maximum distance of your range was only 100 yd., the ballistics table would give you the trajectory of the bullet. As you can see from the chart, you will need to know the weight of the bullet and the velocity. Using the chart for a 130-grain bullet at a velocity of 3,700 feet per second (fps), the bullet will impact the target 0.8 in. above center at 100 yd. with a 200-yd. zero. Adjusting the scope so the bullet impact is 0.8 in. above the point of aim at 100 yd. would produce a zero at 200 yd.

Sighting-in should be done from a steady rest, such as a solid bench rest, tripod, or sandbags. Use a sight-in target like the one shown in Figure 13. These targets are graduated in 1 in. squares to allow easy alignment of a scope. Normally, the paper of these targets is white, which makes it easy to see the bullet holes through a spotting scope or the rifle scope.

To zero-in the rifle, fire a minimum of three shots at the desired range, using the center of the multi-shot group as the hypothetical point

Figure 12: The windage and elevation adjustment on most scopes are covered with caps. Shown next to the uncovered turrets.

Figure 13: A sight-in target.

of impact. The target in Figure 15 is a five-shot group fired from a Ruger Mini-14 at 100 yd. As you can see, the center of the group is 1 in. high and ½ in. to the left.

To adjust the zero of the scope, use a coin or screwdriver and turn the adjusting dials. The scope used for the Ruger Mini-14 has an adjustment of 14 in. per click at 100 yd. This is usually marked on the dial of the scope as shown in Figure 16, or in the instructions that come with the scope.

Since the target was shot at 100 yd., the windage adjustment would be two clicks counterclockwise. The elevation adjustment would be four clicks clockwise. If this target was shot at 200 yd., the adjustments would have been only half as much. After the adjustment is made, another string is shot to verify the hit.

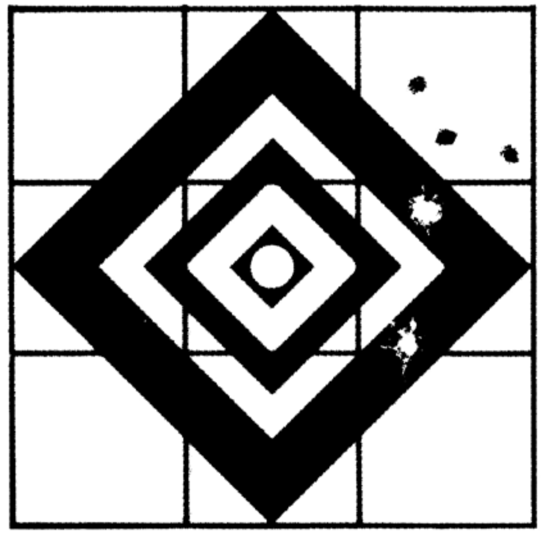

Figure 15: This group was fired from a Ruger Mini-14 at 100 yd.

Handgun Ammunition Product Lines:

AG American Gunner™ | CD Critical Defense® | CDL Critical Defense® Lite | DUTY Critical Duty® | C Custom™ | LEV LEVERevolution® | T TAP® FPD™

Handgun Ballistics

	Ammo Description				Velocity (fps)			Energy (ft/lb)		
	CARTRIDGE	BULLET	ITEM #	BARREL LENGTH	MUZ	50 yd	100 yd	MUZ	50 yd	100 yd
CD	22 WMR	45 gr. FTX®	83200	1 7/8 V″	1000	920	857	100	85	73
C	25 Auto	35 gr. XTP®	90012	2″	900	813	742	63	51	43
C	32 Auto	60 gr. XTP®	90062	4″	1000	905	833	133	109	92
CD	32 NAA	80 gr. FTX®	90070	4″	1000	933	880	178	155	137
CD	32 H&R	80gr. FTX®	90060	4″	1150	1039	963	235	192	165
AG	380 Auto	90 gr. XTP®	90104	4″	1000	912	845	200	166	143
C	380 Auto	90 gr. XTP®	90102	4″	1000	912	845	200	166	143
CD	380 Auto	90 gr. FTX®	90080	4″	1000	912	845	200	166	143
CDL	9mm Luger	100 gr. FTX® CD Lite	90240	4″	1125	1003	922	281	224	189
AG	9mm Luger	115 gr. XTP®	90244	4″	1155	1038	958	341	275	234
CD	9mm Luger	115 gr. FTX®	90250	4″	1135	1025	949	329	268	230
AG	9mm Luger +P	124 gr. XTP®	90224	4″	1175	1074	1001	380	317	276
C	9mm Luger	124 gr. XTP®	90242	4″	1110	1027	965	339	290	257
DUTY	9mm Luger	135 gr. FlexLock®	90236	4″	1010	960	918	306	276	253
DUTY	9mm Luger +P	135 gr. FlexLock®	90226	4″	1110	1038	983	369	323	289
C	9mm Luger	147 gr. XTP®	90282	4″	975	934	899	310	285	264
C	357 Sig	147 gr. XTP®	9131	4″	1225	1132	1060	490	418	367
DUTY	357 Sig	135 gr. FlexLock®	91296	4″	1225	1112	1031	450	371	319
CDL	38 Special	90 gr. FTX® CD Lite	90300	4″	1200	1037	938	288	215	176
CD	38 Special	110 gr. FTX®	90310	4″ V	1010	939	882	249	215	190
CD	38 Special+P	110 gr. FTX®	90311	4″ V	1090	996	928	290	242	210
AG	38 Special	125 gr. XTP®	90324	4″ V	900	856	817	225	203	185
C	38 Special	158 gr. XTP®	90362	4″ V	800	775	751	225	210	198
CD	357 Magnum	125 gr. FTX®	90500	8″ V	1500	1312	1163	624	478	376
AG	357 Magnum	125 gr. XTP®	90504	8″ V	1500	1313	1165	624	479	377
DUTY	357 Magnum	135 gr. FlexLock®	90511	8″ V	1275	1150	1058	487	396	336
LEV	357 Magnum	140 gr. FTX®	92755	8″ V	1440	1281	1154	645	510	414
C	357 Magnum	158 gr. XTP®	90562	8″ V	1250	1149	1072	548	463	403
CD	9 x 18mm Makarov	95 gr. FTX®	91000	4″	1000	913	846	211	176	151
C	40 S&W	155 gr. XTP®	9132	4″	1180	1060	978	479	387	329
CD	40 S&W	165 gr. FTX®	91340	3″	1045	971	914	400	345	306

	Ammo Description				Velocity (fps)			Energy (ft/lb)		
	CARTRIDGE	BULLET	ITEM #	BARREL LENGTH	MUZ	50 yd	100 yd	MUZ	50 yd	100 yd
DUTY	40 S&W	175 gr. FlexLock®	91376	4″	1010	948	899	396	350	314
AG	40 S&W	180 gr. XTP®	91364	4″	950	903	862	361	326	297
C	40 S&W	180 gr. XTP®	9136	4″	950	903	862	361	326	297
C	10mm Auto	155 gr. XTP®	9122	5″	1265	1118	1018	551	430	357
DUTY	10mm Auto	175 gr. FlexLock®	91256	5″	1160	1061	990	523	437	381
C	10mm Auto	180 gr. XTP®	9126	5″	1180	1077	1002	556	463	402
C	44-40 Cowboy	205 gr. Cowboy™	9075	7½″ V	725	689	655	239	216	195
CD	44 Special	165 gr. FTX®	90700	2½″ V	900	847	802	297	263	235
C	44 Special	180 gr. XTP®	9070	7½″ V	1000	934	881	400	349	310
C	44 Rem Mag	200 gr. XTP®	9080	7½″ V	1500	1332	1194	999	788	633
LEV	44 Rem Mag	225 gr. FTX®	92782	7½″ V	1410	1233	1102	993	760	607
C	44 Rem Mag	240 gr. XTP®	9085	7½″ V	1350	1230	1133	971	806	684
C	44 Rem Mag	300 gr. XTP®	9088	7½″ V	1150	1083	1030	881	781	706
AG	45 Auto	185 gr. XTP®	90904	5″	970	911	862	386	341	305
CD	45 Auto	185 gr. FTX®	90900	3″	900	853	811	333	299	270
C	45 Auto	200 gr. XTP®	9112	5″	900	856	817	360	325	296
DUTY	45 Auto +P	220 gr. FlexLock®	90926	5″	975	927	887	464	420	384
C	45 Auto +P	200 gr. XTP®	9113	5″	1055	981	924	494	427	379
C	45 Auto +P	230 gr. XTP®	9096	5″	950	908	871	461	421	388
C	45 Auto	230 gr. FMJ-RN	9097	5″	850	819	790	369	342	319
CD	45 Colt	185 gr. FTX®	92790	3″ V	920	870	826	348	311	280
C	45 Colt	255 gr. Cowboy™	9115	4¾″ V	725	687	651	298	267	240
LEV	45 Colt	225 gr. FTX®	92792	4¾″ V	960	903	855	460	407	366
C	454 Casull	240 gr. XTP® Mag	9148	7½″ V	1900	1678	1478	1924	1500	1164
C	454 Casull	300 gr. XTP® Mag	9150	7½″ V	1650	1474	1319	1813	1447	1158
C	460 S&W Mag	200 gr. FTX®	9152	8 3/8″	2200	1941	1703	2149	1673	1288
C	475 Linebaugh	400 gr. XTP® Mag	9140	7½″	1300	1176	1083	1501	1229	1041
C	480 Ruger	325 gr. XTP® Mag	9138	7½″	1350	1191	1077	1315	1024	837
C	50 AE	300 gr. XTP®	9245	6″	1475	1251	1092	1449	1043	795
C	500 S&W Mag	300 gr. FTX®	9249	8½″	1950	1653	1396	2533	1819	1298
C	500 S&W Mag	500 gr. FP-XTP®	9252	8½″	1300	1178	1085	1876	1541	1308

Muzzleloader Projectile Ballistics

Muzzleloader Ammo Description			Velocity (fps)						Energy (ft/lb)						Trajectory Tables (inches)					
DESCRIPTION	BULLET WT.	ITEM #	MUZ	50 yd	100 yd	150 yd	200 yd	250 yd	MUZ	50 yd	100 yd	150 yd	200 yd	250 yd	MUZ	50 yd	100 yd	150 yd	200 yd	250 yd
45 Cal. SST®-ML™ Low Drag Sabot	200 gr.	67132	2325	2171	2022	1880	1744	1616	2400	2092	1815	1569	1351	1160	-1.5	2.0	3.0	2.0	-1.0	-7.1
50 Cal. SST®-ML™ Lock-N-Load® Speed Sabot®	250 gr.	67270	2250	2031	1852	1684	1529	1389	2735	2290	1904	1574	1297	1070	-1.5	1.8	3.0	1.7	-2.7	-11.0
50 Cal. SST®-ML™ Low Drag Sabot	250 gr.	67273	2250	2031	1852	1684	1529	1389	2735	2290	1904	1574	1297	1070	-1.5	1.8	3.0	1.7	-2.7	-11.0
50 Cal. MonoFlex® Lock-N-Load® Speed Sabot®	250 gr.	67269	2250	2031	1852	1684	1529	1389	2735	2290	1904	1574	1297	1070	-1.5	1.8	3.0	1.7	-2.7	-11.0
50 Cal. MonoFlex® High Speed Low Drag Sabot	250 gr.	67274	2250	2031	1852	1684	1529	1389	2735	2290	1904	1574	1297	1070	-1.5	1.8	3.0	1.7	-2.7	-11.0
50 Cal. SST®-ML™ Lock-N-Load® Speed Sabot®	300 gr.	67271	2130	1974	1826	1686	1554	1433	3022	2597	2221	1893	1609	1368	-1.5	1.9	3.0	1.6	-2.9	-11.1
50 Cal. SST®-ML™ Low Drag Sabot	300 gr.	67263	2130	1974	1826	1686	1554	1433	3022	2597	2221	1893	1609	1368	-1.5	1.9	3.0	1.6	-2.9	-11.1
50 Cal. FPB® *(150 gr. charge)*	300 gr.	6605	2100	1942	1792	1650	1518	1397	2937	2512	2139	1814	1535	1301	-0.9	2.2	3.0	1.1	-8.1	-12.9
50 Cal. FPB® *(100 gr. charge)*	300 gr.	6605	1800	1658	1525	1404	1295	1202	2158	1830	1549	1313	1117	962	-0.9	2.7	3.0	-0.3	-8.1	-21.1
50 Cal. FPB® *(150 gr. charge)*	350 gr.	6600	1950	1821	1697	1581	1473	1372	2955	2577	2238	1942	1685	1463	-1.5	2.0	3.0	0.9	-4.7	-14.2
50 Cal. FPB® *(100 gr. charge)*	350 gr.	6600	1620	1509	1406	1312	1230	1159	2039	1769	1536	1338	1176	1043	-1.5	2.7	3.0	-1.1	-10.2	-25.0

All data developed in a stock T/C Omega inline muzzleloader with 150 gr. charges except when noted. Zero your rifle 3″ high at 100 yards for a 6″ shooting window to 200 yards with 3 pellets or 150 gr. charges.

Figure 14: Sample ballistics table.

The rifle should be zeroed-in just prior to target shooting or hunting, and whenever a different ammunition is used. The two targets in Figure 17 were shot with the same rifle and the same scope setting. The only difference was the type of ammunition used. Figure 17(A) was shot with factory ammunition and Figure 17(B) was shot with reloaded ammunition.

Humidity and other changes in the weather will also alter the bullet impact on the target. So, from time to time, recheck your rifle to see if it is holding its original point of impact. If not, adjust accordingly.

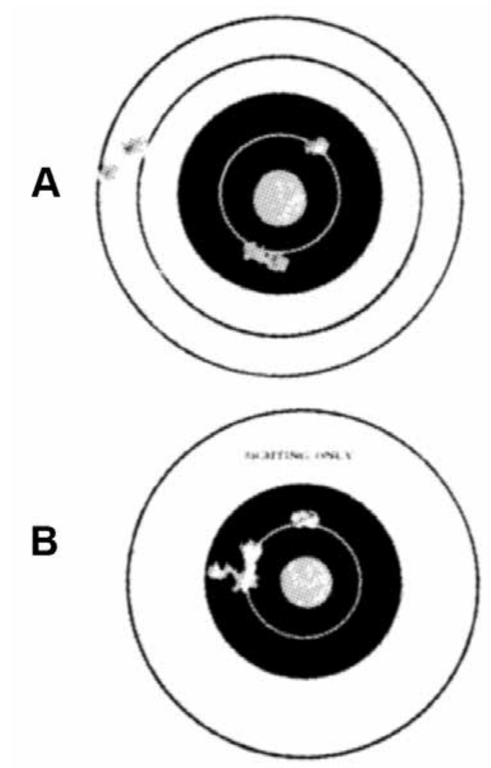

Figure 17: (A) This group was fired using factory ammunition. (B) This group was fired using reloads.

Figure 16: This scope has a ¼ in. per click adjustments.

NOTES

SONORAN
SDI
DESERT
INSTITUTE